Artificial Intelligence for Investment Analysis

投資組合最佳化與程式交易
(Portfolio Optimization and Algorithmic Trading)

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Assistant Professor
Dept. of Information Management, Tamkang University

http://mail.tku.edu.tw/myday/
2018/12/20
週次 (Week) 日期 (Date)  內容 (Subject/Topics)
1 2018/09/13  人工智慧投資分析課程介紹  
(Course Orientation on Artificial Intelligence for Investment Analysis)
2 2018/09/20  AI 金融科技: 金融服務創新應用  
(AI in FinTech: Financial Services Innovation and Application)
3 2018/09/27  機器人理財顧問與AI交談機器人  
(Robo-Advisors and AI Chatbots)
4 2018/10/04  投資心理學與行為財務學  
(Investing Psychology and Behavioral Finance)
5 2018/10/11  財務金融事件研究法 (Event Studies in Finance)
6 2018/10/18  人工智慧投資分析個案研究 I  
(Case Study on Artificial Intelligence for Investment Analysis I)
課程大綱 (Syllabus)

週次 (Week) 日期 (Date) 內容 (Subject/Topics)
7 2018/10/25 Python AI投資分析基礎 (Foundations of AI Investment Analysis in Python)
8 2018/11/01 Python Pandas量化投資分析 (Quantitative Investing with Pandas in Python)
9 2018/11/08 Python Scikit-Learn 機器學習 (Machine Learning with Scikit-Learn in Python)
10 2018/11/15 期中報告 (Midterm Project Report)
<table>
<thead>
<tr>
<th>項次 (Week)</th>
<th>日期 (Date)</th>
<th>內容 (Subject/Topics)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>2018/12/06</td>
<td>人工智慧投資分析個案研究 II (Case Study on Artificial Intelligence for Investment Analysis II)</td>
</tr>
<tr>
<td>15</td>
<td>2018/12/20</td>
<td>投資組合最佳化與程式交易 (Portfolio Optimization and Algorithmic Trading)</td>
</tr>
<tr>
<td>16</td>
<td>2018/12/27</td>
<td>自然語言處理 (Natural Language Processing)</td>
</tr>
<tr>
<td>17</td>
<td>2019/01/03</td>
<td>期末報告 I (Final Project Presentation I)</td>
</tr>
<tr>
<td>18</td>
<td>2019/01/10</td>
<td>期末報告 II (Final Project Presentation II)</td>
</tr>
</tbody>
</table>
Portfolio Optimization and Algorithmic Trading
Outline

• Portfolio Optimization

• Algorithmic Trading
Portfolio Optimization
Algorithmic Trading
Yves Hilpisch,
Python for Finance: Analyze Big Financial Data,
O'Reilly, 2014

Source: http://www.amazon.com/Python-Finance-Analyze-Financial-Data/dp/1491945281
Yves Hilpisch (2015),
Derivatives Analytics with Python:
Data Analysis, Models, Simulation, Calibration and Hedging, Wiley


Algorithmic Trading

Historical Finance Market Data -> Computer Program

Computer Program -> Backtest Results

Computer Program -> Live Finance Market Data

Live Finance Market Data -> Broker API

Broker API -> Broker’s Server

Broker’s Server -> Order

Order -> Order Status

Order Status -> Order

FinTech Innovation: From Robo-Advisors to Goal Based Investing and Gamification, Paolo Sironi, Wiley, 2016
FinTech: Financial Services Innovation

Source: http://www3.weforum.org/docs/WEF_The_future__of_financial_services.pdf
FinTech: Financial Services Innovation

1. Payments
2. Insurance
3. Deposits & Lending
4. Capital Raising
5. Investment Management
6. Market Provisioning

Source: http://www3.weforum.org/docs/WEF_The_future__of_financial_services.pdf
5 FinTech: Investment Management

Source: http://www3.weforum.org/docs/WEF_The_future__of_financial_services.pdf
FinTech: Investment Management
Empowered Investors
Process Externalization

Source: https://www.stockfeel.com.tw/2015年世界經濟論壇－未來的金融服務/
FinTech: Market Provisioning

Source: http://www3.weforum.org/docs/WEF_The_future__of_financial_services.pdf
FinTech: Market Provisioning
Smarter, Faster Machines
New Market Platforms
The Quant Finance PyData Stack

Quantopian

PyThalesians

Zipline

DX Analytics

PyAlgoTrade

QuantLib

StatsModels

NetworkX

scikits-image

matplotlib

pandas

SciPy

NumPy

SymPy

IPython

Python

jupyter

Source: http://nbviewer.jupyter.org/format/slides/github/quantopian/pyfolio/blob/master/pyfolio/examples/overview_slides.ipynb#5
Zipline

a Pythonic Algorithmic Trading Library

http://www.zipline.io/

Source: https://github.com/quantopian/zipline
Zipline

• Zipline: Pythonic algorithmic trading library.
• Event-driven system
  – supports both backtesting and live-trading.
• Zipline is currently used in production as the backtesting and live-trading engine powering Quantopian
  – a free, community-centered, hosted platform for building and executing trading strategies.

Source: http://www.zipline.io/
Quantopian

Become an Expert in Quant Finance
Quantopian provides free education, data, and tools so anyone can pursue quantitative finance. Select members license their algorithms and share in the profits.

Start Learning

Community Achievements
All numbers are as of June 1, 2018

https://www.quantopian.com/
Sign up for Quantopian

Research and Develop Your Investment Ideas

First name

Last name

Email address

Create a password

Get started

I accept the Terms Of Use and Privacy Policy.

https://www.quantopian.com/users/sign_up
Quantopian
Sample Mean Reversion Algorithm

Settings: From 2015-03-27 to 2017-05-24 with $1,000,000 initial capital
Calendar: US Equities
Status: ✔ Backtest complete

Results Overview

<table>
<thead>
<tr>
<th>Results Overview</th>
<th>Total Returns</th>
<th>Benchmark Returns</th>
<th>Alpha</th>
<th>Beta</th>
<th>Sharpe</th>
<th>Sortino</th>
<th>Volatility</th>
<th>Max Drawdown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-13.4%</td>
<td>22.2%</td>
<td>-0.08</td>
<td>0.13</td>
<td>-0.82</td>
<td>-1.15</td>
<td>0.08</td>
<td>-17.3%</td>
</tr>
</tbody>
</table>

Cumulative performance: Algorithm -13.24% Benchmark (SPY) 21.9%

Source: https://www.quantopian.com/algorithms/59274d707875d1000d41937d/5927506f3cf7da6fec5951b6#backtest
## Quantopian Sample Mean Reversion Algorithm

**Settings:** From 2015-03-27 to 2017-05-24 with $1,000,000 initial capital

**Calendar:** US Equities

**Status:** Backtest complete

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Returns</td>
<td>-13.4%</td>
</tr>
<tr>
<td>Benchmark Returns</td>
<td>22.2%</td>
</tr>
<tr>
<td>Alpha</td>
<td>-0.08</td>
</tr>
<tr>
<td>Beta</td>
<td>0.13</td>
</tr>
<tr>
<td>Sharpe</td>
<td>-0.82</td>
</tr>
<tr>
<td>Sortino</td>
<td>-1.15</td>
</tr>
<tr>
<td>Volatility</td>
<td>0.08</td>
</tr>
<tr>
<td>Max Drawdown</td>
<td>-17.3%</td>
</tr>
</tbody>
</table>

Cumulative performance: **Algorithm** -3.3%  **Benchmark (SPY)** -5.02%

Source: [Quantopian Sample Mean Reversion Algorithm](https://www.quantopian.com/algorithms/59274d707875d1000d41937d/5927506f3cf7da6fec5951b6#backtest)
Quantopian

Sample Mean Reversion Algorithm

Settings:
- From 2015-03-27 to 2017-05-24 with $1,000,000 initial capital
- Calendar: US Equities
- Status: Backtest complete

Results Overview
- Total Returns: -13.4%
- Benchmark Returns: 22.2%
- Alpha: -0.08
- Beta: 0.13
- Sharpe: -0.82
- Sortino: -1.15
- Volatility: 0.08
- Max Drawdown: -17.3%

Cumulative performance:
- Algorithm: -11.1%
- Benchmark (SPY): 6.8%

Custom data:
- short_count 150
- long_count 150
- leverage 0.96

Weekly returns: $3,535

Transactions

Source: https://www.quantopian.com/algorithms/59274d707875d1000d41937d/5927506f3cf7da6fec5951b6#backtest
### Sample Mean Reversion Algorithm

**Settings:** From 2015-03-27 to 2017-05-24 with $1,000,000 initial capital

**Calendar:** US Equities

**Status:** Backtest complete

### Transaction Details

<table>
<thead>
<tr>
<th>Date</th>
<th>Asset</th>
<th>Transaction</th>
<th>Unit Price</th>
<th>Quantity</th>
<th>Position Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>PRAA</td>
<td>SELL</td>
<td>$37.32</td>
<td>-2</td>
<td>($74.65)</td>
</tr>
<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>PRTA</td>
<td>SELL</td>
<td>$55.83</td>
<td>-31</td>
<td>($1,730.64)</td>
</tr>
<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>PSTG</td>
<td>BUY</td>
<td>$11.68</td>
<td>44</td>
<td>$513.96</td>
</tr>
<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>PTCT</td>
<td>SELL</td>
<td>$13.31</td>
<td>-10</td>
<td>($133.09)</td>
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<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>QLYS</td>
<td>BUY</td>
<td>$43.50</td>
<td>10</td>
<td>$435.03</td>
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<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>RGR</td>
<td>SELL</td>
<td>$64.07</td>
<td>-2</td>
<td>($128.14)</td>
</tr>
<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>RRD</td>
<td>BUY</td>
<td>$13.30</td>
<td>62</td>
<td>$824.60</td>
</tr>
<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>RXN</td>
<td>BUY</td>
<td>$23.45</td>
<td>9</td>
<td>$211.05</td>
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<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>SUPN</td>
<td>SELL</td>
<td>$33.50</td>
<td>-12</td>
<td>($401.98)</td>
</tr>
<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>TCO</td>
<td>SELL</td>
<td>$59.08</td>
<td>-7</td>
<td>($413.54)</td>
</tr>
<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>TIVO</td>
<td>BUY</td>
<td>$17.15</td>
<td>2</td>
<td>$34.30</td>
</tr>
<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>TLRD</td>
<td>BUY</td>
<td>$12.11</td>
<td>52</td>
<td>$629.77</td>
</tr>
<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>TROX</td>
<td>SELL</td>
<td>$19.21</td>
<td>-60</td>
<td>($1,152.54)</td>
</tr>
<tr>
<td>2017-05-15 - 11:07 PM</td>
<td>TWIN</td>
<td>BUY</td>
<td>$15.69</td>
<td>17</td>
<td>$266.75</td>
</tr>
</tbody>
</table>

Source: https://www.quantopian.com/algorithms/59274d707875d1000d41937d/592756885310d86a415cb0e1#backtest
Quantopian
Sample Mean Reversion Algorithm

Settings: From 2007-01-01 to 2016-12-31 with $1,000,000 initial capital
Calendar: US Equities

Source: https://www.quantopian.com/algorithms/59274d707875d1000d41937d/592756885310d86a415cb0e1#backtest
Quantopian
Sample Mean Reversion Algorithm

<table>
<thead>
<tr>
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<th>Alpha</th>
<th>Beta</th>
<th>Sharpe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11%</td>
<td>93.2%</td>
<td>0.01</td>
<td>0.07</td>
<td>0.16</td>
</tr>
</tbody>
</table>

Cumulative performance:  
- **Algorithm**: 10.97%  
- **Benchmark (SPY)**: 94.12%
Risk and Return

Sharpe Ratio

$\text{Sharpe Ratio} = \frac{\text{Portfolio Return} - \text{Risk Free Return}}{\text{Portfolio Risk}}$
Sharpe Ratio

\[
SR = \frac{r_P - r_F}{\sigma_P}
\]

Where

- \(r_P\) = portfolio return
- \(r_F\) = risk free rate
- \(\sigma_P\) = portfolio risk (variability, standard deviation of return)

Sortino Ratio

\[
\text{Sortino Ratio} = \frac{r_P - r_T}{\sigma_D}
\]

Where

- \( r_P \) = portfolio return
- \( r_T \) = Minimum Target Return
- \( \sigma_D \) = Downside Risk

Downside Risk \( \sigma_D \) = 

\[
\sqrt{\frac{\sum_{i=1}^{n} \min[(r_i - r_T), 0]^2}{n}}
\]

Max Drawdown

This is a sample mean-reversion algorithm on Quantopian for you to test and adopt. This example uses a dynamic stock selector, pipeline, to select stocks to trade. It orders stocks from the top 1% of the previous day’s dollar-volume (liquid stocks).

Algorithm investment thesis:
Top-performing stocks from last week will do worse this week, and vice-versa.

Every Monday, we rank high dollar-volume stocks based on their previous 5 day returns. We long the bottom 10% of stocks with the WORST returns over the past 5 days. We short the top 10% of stocks with the BEST returns over the past 5 days.

This type of algorithm may be used in live trading and in the Quantopian Open.

```
# Import the libraries we will use here.
from quantopian.algorithm import attach_pipeline, pipeline_output
from quantopian.pipeline import Pipeline
from quantopian.pipeline.data.builtin import USEquityPricing
from quantopian.pipeline.factors import Returns
from quantopian.pipeline.filters.morningstar import Q1500US

def initialize(context):
    """
    Called once at the start of the program. Any one-time
    startup logic goes here.
    """
    # Define context variables that can be accessed in other methods of
    # the algorithm.
    context.long_leverage = 0.5
    context.short_leverage = -0.5
    context.lookback = 5

    # Rebalance on the first trading day of each week at 11AM.
    schedule_function(rebalance,  
                      date_rules.week_start(days_offset=0),  
                      time_rules.market_open(hours=1, minutes=30))

    # Record tracking variables at the end of each day.
    schedule_function(record_vars,  
                      date_rules.every_day())
```

Source: https://www.quantopian.com/algorithms/59274d707875d1000d41937d/5927506f3cf7da6fec5951b6#backtest
Quantopian
Sample Mean Reversion Algorithm

This is a sample mean-reversion algorithm on Quantopian for you to test and adapt. This example uses a dynamic stock selector, pipeline, to select stocks to trade. It orders stocks from the top 1% of the previous day’s dollar-volume (liquid stocks).

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Source: https://www.quantopian.com/algorithms/59274d707875d1000d41937d/5927506f3cf7da6fec5951b6#backtest
Writing and Backtesting an Algorithm on Quantopian

Source: https://www.quantopian.com/tutorials/getting-started
What is a Trading Algorithm?

On Quantopian, a trading algorithm is a Python program that defines two special functions: `initialize()` and `handle_data()`.

Source: [https://www.quantopian.com/tutorials/getting-started](https://www.quantopian.com/tutorials/getting-started)
An example of an algorithm that allocates 100% of its portfolio in AAPL

```python
def initialize(context):
    # Reference to AAPL
    context.aapl = sid(24)

def handle_data(context, data):
    # Position 100% of our portfolio to be long in AAPL
    order_target_percent(context.aapl, 1.00)
```

Source: [https://www.quantopian.com/tutorials/getting-started](https://www.quantopian.com/tutorials/getting-started)
def initialize(context):
    context.security = symbol('AAPL')
    schedule_function(myfunc, date_rules.every_day(), time_rules.market_open(minutes = 15))

def handle_data(context, data):
    MovingAvg1 = data[context.security].mavg(20)
    MovingAvg2 = data[context.security].mavg(60)

    current_positions = context.portfolio.positions[symbol('AAPL')].amount

    if (MovingAvg1 > MovingAvg2) and current_positions == 0:
        order_target_percent(context.security, 0.25)

    elif (MovingAvg1 < MovingAvg2) and current_positions != 0:
        order_target(context.security, 0)
Quantopian
WSJ Example Algorithm

Cloned from "WSJ Example Algorithm"

Settings: From 2009-01-01 to 2011-01-01 with $1,000,000 initial capital
Calendar: US Equities
Status: Backtest complete

Results Overview

Total Returns 46.3%  Benchmark Returns 45.4%  Alpha 0.16  Beta 0.16  Sharpe 1.82  Sortino 2.89  Volatility 0.11  Max Drawdown -12.1%

Cumulative performance: Algorithm 46.3%  Benchmark (SPY) 45.4%

Custom data: num_positions 299

Daily returns $963

Source: https://www.quantopian.com/algorithms/59274d707875d1000d41937d/5927506f3cf7da6fec5951b6#backtest
Investment Science: Portfolio Optimization

Source: Tucker Balch (2012), Investment Science: Portfolio Optimization, https://www.youtube.com/watch?v=5qbMhXXq0vl
Portfolio Optimization
Efficient Frontier

Source: Tucker Balch (2012), Investment Science: Portfolio Optimization, https://www.youtube.com/watch?v=5qbMhXXq0vl
Portfolio Optimization and Algorithmic Trading

```python
# locate position of portfolio with highest Sharpe Ratio
max_sharpe_port = results_frame.iloc[results_frame['sharpe'].idxmax()]

# locate position of portfolio with minimum standard deviation
min_vol_port = results_frame.iloc[results_frame['stdev'].idxmin()]

# create scatter plot coloured by Sharpe Ratio
plt.figure(figsize=(10, 6))
plt.scatter(results_frame['stdev'], results_frame['ret'], c=results_frame['sharpe'], cmap='RdYlBu')
plt.xlabel('Volatility')
plt.ylabel('Returns')

# plot red star to highlight position of portfolio with highest Sharpe Ratio
plt.scatter(max_sharpe_port[1], max_sharpe_port[0], marker=(5, 1, 0), color='r', s=1000)

# plot green star to highlight position of minimum variance portfolio
plt.scatter(min_vol_port[1], min_vol_port[0], marker=(5, 1, 0), color='g', s=500)
```

https://colab.research.google.com/drive/1nN5yOB3ZFXKxq4y9WwzCVTV1i_BVpfAD
Portfolio Optimization

Efficient Frontier

Portfolio Optimization with Individual Stocks

- Efficient frontier
- Maximum Sharpe ratio
- Minimum volatility

- GOOG (GOOG)
- AAPL
- FB
- AMZN
优矿，您的私人量化平台
打破金融量化的壁垒，为量化研究者提供媲美华尔街专业机构的研究装备

了解专业版>>>
海量金融大数据
高质量的海量金融数据支撑，轻松实现大数据时代的交易策略

云端平台，高效研究，极速回测
稳定、安全、高可扩展的云平台，零门槛获得华尔街专业级别量化研究装备

Source: https://uquer.io/home/
模拟交易，赢取基金管理权

一键实盘模拟，云端托管，更有机会赢取500万实盘资金管理收益
策略广场

赢率季胜季
策略收益 305.71%  基准收益
最大回撤 13.31%  初始资金  ¥50000
已有540人订阅
免费订阅

基于SVM的机器学习策略
策略收益 10.05%  基准收益
最大回撤 20.49%  初始资金  ¥100000
已有633人获取源码
获取源码

稳增高爆组合
策略收益 142.52%  基准收益
最大回撤 15.88%  初始资金  ¥100000
已有585人订阅
免费订阅

银行日内
策略收益 78.64%  基准收益
最大回撤 4.51%  初始资金  ¥30000

【量化课堂】股指期货期套... JoinQuant量化课堂
策略收益 56.11%  基准收益
最大回撤 17.13%  初始资金  ¥100000

分级A轮动策略
策略收益 18.58%  基准收益
最大回撤 1.08%  初始资金  ¥30000

Source: https://www.joinquant.com/
策略研究

免费提供IPython Notebook研究平台以及强大的金融、数学等工具库
免费提供10年+的日、分钟级历史数据以及400多项指标的财务数据
灵活的文本编辑和绘图功能，提供无与伦比的交互式体验

Source: https://www.ricequant.com/
历史回测

强大、易用的量化接口API，易于编写交易策略
免费提供10年+的日、分钟级历史数据以及400多项指标的财务数据
极速、精准的回测体验，快速开发和验证投资策略

Source: https://www.ricequant.com/
实时模拟交易

一键部署，云端永久运行
微秒级别实时数据推送计算
将会提供微信、邮件等交易信号推送
# 可以自己import我们平台支持的第三方python模块，比如pandas、numpy等。

# 在这个方法中编写任何的初始化逻辑。context对象将会在你的算法策略中任意方法之间做传递。

def init(context):
    context.s1 = "00001.XSHE"
    # 实时打印日志
    logger.info("Interested at stock: " + str(context.s1))

# before_trading此函数会在每天交易开始前被调用，当天只会被调用一次

def before_trading(context, bar_dict):
    pass

# 你可以选择的股票的数据更新将会触发此段逻辑，例如日或分钟历史数据切片或者是实时数据切片更新

def handle_bar(context, bar_dict):
    # 开始编写你的主要的算法逻辑
    # bar_dict[order_book_id] 可以拿到某个证券的bar信息
    # context.portfolio 可以拿到现在的投资组合状态信息
    # 使用order_shares(id_or_ins, amount)方法进行下单

    # T000：开始编写你的算法吧！
    order_shares(context.s1, 1000)
RiceQuant

```python
# 在这个方法中编写任何的初始化逻辑。context对象将会在你的算法策略的任何方法之间做传递。
def init(context):
    #沪深300指数、中证500指数和国债指数
    context.stocks = ['000300.XSHG', '000905.XSHG', '000912.XSHG']
    # before_trading此函数会在每天交易开始前被调用，当天只会被调用一次
    # 你选择的证券的数据更新将会触发此段逻辑，例如日或分钟历史数据切片或者是实数数据切片更新
    def handle_bar(context, bar_dict):
        # 开始编写你的主要的算法逻辑
        hs300 = history_bars(context.stocks[0], 20, "1d", "close")
        zz500 = history_bars(context.stocks[1], 20, "1d", "close")
        hsIncrease = hs300[19] - hs300[0]
        zzIncrease = zz500[19] - zz500[0]
        p = context.portfolio.positions
        hsQuality = p[context.stocks[0]].quantity
        zzQuality = p[context.stocks[1]].quantity
        gzQuality = p[context.stocks[2]].quantity

        if hsIncrease < 0 and zzIncrease < 0:
            if hsQuality > 0:
                order_target_percent(context.stocks[0], 0)
                logger.info("卖出沪深300")
            if zzQuality > 0:
                order_target_percent(context.stocks[1], 0)
                logger.info("卖出中证500")
            if gzQuality <= 0.001:
                order_target_percent(context.stocks[2], 1)
                logger.info("买入国债")
        elif hsIncrease < zzIncrease:
            if hsQuality > 0:
                order_target_percent(context.stocks[0], 0)
                logger.info("卖出沪深300")
            if gzQuality > 0:
                order_target_percent(context.stocks[2], 0)
                logger.info("卖出国债")
            if zzQuality <= 0.001:
```

Source: https://www.ricequant.com/algorithm/523092
MultiCharts 12
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More exciting features & improvements

https://www.multicharts.com/
```python
# !pip install pandas_datareader
import pandas as pd
import pandas_datareader.data as web
import matplotlib.pyplot as plt
import seaborn as sns
import datetime as dt

# Read Stock Data from Yahoo Finance
end = dt.datetime.now()
start = dt.datetime(2016, 1, 1)
df = web.DataReader('AAPL', 'yahoo', start, end)
df.to_csv('AAPL.csv')
df.tail()

df[['Adj Close']].plot(legend=True, figsize=(12, 8), title='AAPL', label='Adj Close')
plt.figure(figsize=(12,9))
top = plt.subplot2grid((12,9), (0,0), rowspan=10, colspan=9)
bottom = plt.subplot2grid((12,9), (10,0), rowspan=2, colspan=9)
top.plot(df.index, df['Adj Close'], color='blue')  # df.index gives the dates
bottom.bar(df.index, df['Volume'])

# set the labels
top.axes.get_xaxis().set_visible(False)
top.set_title('AAPL')
top.set_ylabel('Adj Close')
bottom.set_ylabel('Volume')

plt.figure(figsize=(12,9))
sns.distplot(df['Adj Close'].dropna(), bins=50, color='purple')

# simple moving averages
df['MA05'] = df['Adj Close'].rolling(5).mean()  # 5 days
df['MA20'] = df['Adj Close'].rolling(20).mean()  # 20 days
df['MA60'] = df['Adj Close'].rolling(60).mean()  # 60 days
df['pda'] = pd.DataFrame({'Adj Close': df['Adj Close'], 'MA05': df['MA05'], 'MA20': df['MA20'], 'MA60': df['MA60']})
df2.plot(figsize=(12, 9), legend=True, title='AAPL')
df2.to_csv('AAPL_MA.csv')
fig = plt.gcf()
fig.set_size_inches(12, 9)
fig.savefig('AAPL_plot.png', dpi=300)
```
Deep Learning for Financial Time Series Forecasting

Source: https://machinelearningmastery.com/how-to-develop-lstm-models-for-time-series-forecasting/

```python
# univariate lstm example
from numpy import array
from keras.models import Sequential
from keras.layers import LSTM
from keras.layers import Dense
import matplotlib.pyplot as plt
%matplotlib inline

# define dataset
X = array([[100, 110, 120], [110, 120, 130], [120, 130, 140], [130, 140, 150], [140, 150, 160]])
y = array([130, 140, 150, 160, 170])
# reshape from [samples, timesteps] into [samples, timesteps, features]
X = X.reshape((X.shape[0], X.shape[1], 1))
# define model
model = Sequential()
model.add(LSTM(50, activation='relu', input_shape=(3, 1)))
model.add(Dense(1))
model.compile(optimizer='adam', loss='mse')
# fit model
history = model.fit(X, y, epochs=2000, verbose=0)
# demonstrate prediction
x_input = array([[150, 160, 170]])
x_input = x_input.reshape((1, 3, 1))
yhat = model.predict(x_input, verbose=0)
print('yhat', yhat)
print(model.summary())
# list all data in history
print(history.history.keys())
# summarize history for loss
print('Loss', 'epoch')
print('loss', 'loss')
plt.plot(history.history['loss'])
plt.title('model loss')
plt.ylabel('loss')
plt.xlabel('epoch')
yhat ([[181.34615]])
```

https://colab.research.google.com/drive/1aEK0eSev8Q-Y0nNY32geFk7CB8pVgSQM
Summary

• Portfolio Optimization

• Algorithmic Trading
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• Ricequant, https://www.ricequant.com/
• MultiCharts, https://www.multicharts.com/