Colin Powell School
for Civic and Global Leadership

The City College of New York

Quantitative Finance - ECO 41552-ONL (Fall 2022)
Tue/Thu 11am – 12:15pm, Aug 25 – Dec 21, 2022

Instructor: John Droescher | jdroescher@ccny.cuny.edu | Office Hours: Fri 4 – 6pm

Course Description:
This course teaches Python Programming and applies Quantitative Portfolio Theory to understand and evaluate investment products and trading/investing strategies in the context of the empirical evidence about return patterns across assets (*i.e.*, the factors such as value/growth, momentum, and carry that drive returns) in multiple markets/asset classes (*e.g.*, domestic and international equities and bonds, currencies, and commodities). This course will be financial economics intensive, but the ability to develop alpha signals through analyzing large datasets by programming in Python is crucial to have in a career in marketing, human resources, business operations, and economics.

Learning Outcomes:
- Develop an understanding of the logic behind programming solutions
- Develop deeper understanding of Python programming and how to use Pandas, NumPy, and MatPlotLib
- Understand the Markowitz efficient frontier and its uses
- Identify and apply alpha generating factors
- Critically examine current financial markets using Python to develop a model of how assets are performing
- Obtain a foundational introduction to machine learning and its applications in Finance (and elsewhere)

Required Books:
Python for Finance: Mastering Data-Driven Finance, Author: Hilpisch, Yves, Publisher: O'Reilly Media, Incorporated, Edition: 2, Year Published: 2018 (PFF)

Hands-On Machine Learning with Scikit-Learn and TensorFlow, Author: Geron, Aurelien, Publisher: O'Reilly Media Incorported, Edition: 1, Year Published: 2017 (ML)

Course Requirements and Grading:
This course has three projects that account for 90% of the grade. Attendance is not required but attendance and participation are highly encouraged (for your benefit). Each week will have a short coding assignment. All assignments will be delivered through GitHub.

Grade Breakdown	
Weekly Code Practice	10%
Portfolio Analysis	25%
Efficient Frontier	25%
Final Project	40%

Technology:
This course, of course, requires extensive use of Python, along with Teams and Zoom. Python can be installed on your personal computer and accessed using the interface of your choice. For a local install, I recommend VSCode. I also have a server that is accessible remotely that hosts JupyterLab (and can be switched to Jupyter Classic).

For communication, we will use primarily Teams. Zoom will be used for lectures, although watching posted lectures does not require installation of Zoom software.

Additionally, for submitting code assignments, the class will have a GitHub repository.

Cheating and Plagarism:

Copying other's work and passing it off as your own will not be tolerated. Cheating and/or plagiarism will lead to failing the course and possibly being expelled from City College. If you have any doubts about what plagiarism is, please ask me or visit the following website to familiarize yourself with the rules of academic honesty: https://www.cuny.edu/about/administration/offices/legal-affairs/policies-procedures/academic-integrity-policy/

Course Outline:

Week 1:

Review of Python Fundamentals – Installing JupyterLab, Installing Python Libraries, Calling Libraries, Use of NumPy, and Review of Fundamental Python Structures (Lists, Tuples, Dictionaries, Sets).

Introduce Factors and Project – Portfolio Analysis, Markowitz Efficient Frontier, Berry Cox's Alpha Generating Factors, Introduce Term Projects.

Chapter 4: NumPy and Pandas – Dataframes, Groupby, Merging/Joining/Concatenating Dataframes, Data Input and Outputs Using Pandas. Datetime Indexing, Time Resampling, Time Shifts, Pandas Rolling and Expanding.

Week 2:

Writing Good Code, Algorithm Design – There is more to writing code than just whether it works.

Python Finance Fundamentals – Sharpe Ratio, Types of Funds, CAPM, Stock Splits and Dividends.

Chapter 5: Data Analysis with Pandas – Performance aspects, how to make our code faster.

Chapter 6: Object-Oriented Programming – Python Classes and the Python Data Model.

Week 3:

Python Object-Oriented Programming Redux – Creating your own functions to streamline your processes.

Chapter 7: Data Visualization – Static 2D and 3D modeling to make informative charts.

Chapter 8: Financial Time Series – Analyzing Financial Data, Rolling Statistics, Correlation Analysis, and High Frequency Data.

Chapter 9: Input/Output Operations – Basic I/O with Python, Pandas, PyTables, and TsTables. How do we pull in data from CSV files or a SQL database?

Week 4:

Data Cleaning, An Introduction to Feature Engineering: How do we choose features, categorical conversion, normalization and standardization

Chapter 10: Performance Python – Creating Loops, Building your Algorithm, Binomial Trees, a Monte Carlo Simulation, Recursive Pandas Algorithms.

Chapter 11: Mathematical Tools – Approximation, Convex Optimization, Integration, Symbolic Computation.

Sep 30: First Project Due – Portfolio Analysis

Week 5:

Discussing the Portfolio Analysis Project – Lessons Learned

The Efficient Frontier Realized – Returning to the efficient frontier to discuss more in-depth what it is, and how it works.

Chapter 12: Stochastics – Random Numbers, Simulation, Valuation, Risk Measures.

Chapter 13: Statistics – Normality Tests, Portfolio Optimization Redux, Bayesian Statistics, an Introduction to Machine Learning.

Week 6:

Python Web-Scraping – How do we use Python to parse through a website, article, or stock filing to retrieve alpha information?

Chapter 15: Trading Strategies – Simple Moving Averages, Berry Cox's Alpha Generating Factors, Linear OLS Regression, Random Walk Hypothesis, Frequency Approach, An Introduction to Deep Neural Networks.

Chapter 16: Automated Trading – Capital Management, Strategy Monitoring, Backtesting.

Week 7:

Module 7: Consumption, Savings, and Growth – Cake Eating, Optimal Growth Models, Income Fluctuation Problem, Returns on Assets.

Chapter 17: Valuation Framework – Fundamental Theorem of Asset Pricing, Risk-Neutral Discounting, Market Environments.

Chapter 18: Simulation of Financial Models – Random Number Generation, Generic Simulation Class, Geometric Brownian Motion, Jump Diffusion, Square-Root Diffusion.

Week 8:

Module 8: Information – Search with Learning, Likelihood Ratio Processes, a problem that stumped Milton Friedman, Bayesian Learning.

Chapter 19: Derivatives Valuation – Generic Valuation Class, European and American Exercises.

Chapters 20 and 21: Portfolio Valuation and Market-Based Valuation – Derivatives Positions and Derivatives Portfolios, Options Data, Model Calibration, Portfolio Valuation.

Oct 31: Second Project Due – Efficient Frontier

Week 9:

Discussing the Efficient Frontier Project – Lessons Learned

Attacking the Capstone Project

Module 8: Information (cont.) – Search with Learning, Likelihood Ratio Processes, a problem that stumped Milton Friedman, Bayesian Learning.

Chapter 1: The Machine Learning Landscape – A more in-depth introduction to machine learning

Chapter 2: End-to-End Machine Learning Project – What does an ML algorithm/model look like in practice? Performance Evaluation.

Week 10:

Return of the Regression – what really is regression: why do we do it, what does it tell us, how do we interpret it in finance?

Linear Algebra and Numpy – Let's do some applied matrix math!

Chapter 3: Classification – Binary and Multi-class classifiers.

Week 11:

Gradient Descent – What do mountain climbing and rivers have to do with machine learning and finance?

Chapter 4: Training Models – Linear Regressions, Gradient Descent, Polynomial Regressions, Regularized models, Logistic Regression

Week 12:

Support Vector Machines – Another type of regression and the seeds of classification.

Chapter 5: Support Vector Machines – Linear and Nonlinear SVM Classification, SVM Regression

Nov 30: Final Project Draft Due – Long/Short Trading Strategy w/Backtest

Week 13:

Decision Trees, Ensemble Learning, Random Forests – The building blocks of deep learning. And how do we combine the best of all these different models?

Chapter 6: Decision Trees

Chapter 7: Ensemble Learning and Random Forests – Voting Classifiers, Bagging, Random Forests, and Boosting.

Week 14:

Feature Engineering Redux – Wait, there's more to this? And it's easier...? Dimensionality, the curse and the cure. Primary Component Analysis. Automated ML – a starting point.

Chapter 8: Dimensionality Reduction

Week 15:

An Introduction to Neural Networks and Deep Learning – What is a Neural Network? How does it work? Where is this applied and how do we use it in Finance?

Chapter 10: An Introduction to Artificial Neural Networks
Chapter 13: Convolutional Neural Networks
Chapter 14: Recurrent Neural Networks

Week 16:

Semester Wrap – Final Project Presentations?

Dec 21: Final Project Due – Long/Short Trading Strategy w/Backtest