Python and Decentralized Finance

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Course Description

The course aims to provide a broad understanding, principles, and techniques of Decentralized Finance (DeFi) and Python coding for the most popular quantitative applications in Traditional Finance (TradFi), widely used in the financial industry and academic research.

DeFi is transforming global finance with blockchain-based transparent and accessible systems. This course introduces DeFi's foundations, key components, and impact, covering dApps, smart contracts, tokenized assets, DEXs, lending platforms, stablecoins, liquidity pools, and yield farming. It also addresses governance, risks, and regulations, preparing students to engage with and innovate in the DeFi ecosystem.

The course will cover various topics, with an emphasis on the hands-on implementation of those ideas in Python and intuitively visualized output. A short introduction to Python (and some of the important packages) is given at the start of the course. The necessary historical financial data will be downloaded via various APIs straight from the web.

The course roughly splits into two parts (see below for more information): i) DeFi and ii) TradFi.

DeFi

I. DeFi Infrastructure (Blockchain, Smart Contracts, Important Protocols)

DeFi infrastructure uses blockchain and smart contracts to enable decentralized, transparent, and automated financial systems. Key protocols like Ethereum, Solana, and Avalanche provide platforms for DeFi applications, while foundational tools like Uniswap, Aave, and MakerDAO showcase the power of decentralized innovation.

II. Cryptocurrencies, Stablecoins

Cryptocurrencies like Bitcoin and Ethereum are digital assets used for exchange, value storage, and investment. Stablecoins, pegged to assets like fiat currencies, offer stability, bridging volatile crypto with traditional finance for payments and DeFi collateral.

III. Decentralized Exchange (DEX) and Automated Market Makers (AMMs)

DEXs enable peer-to-peer crypto trading on the blockchain, ensuring transparency and user control. Powered by AMMs, which use liquidity pools and algorithmic pricing, they provide continuous liquidity without intermediaries. While AMMs like Uniswap and Curve simplify trading, they face challenges such as impermanent loss, price slippage, and front-running in low-liquidity pools. Despite these risks, AMMs are central to DeFi.

IV. Other DeFi Applications (Flash Loans, Sandwich attacks, ...)

DeFi innovations include flash loans, instant unsecured loans for arbitrage, and vulnerabilities like sandwich attacks, where traders exploit price manipulation, highlighting security challenges.

V. Real World Assets (RWAs) and Tokenized Money Market Funds (TMMFs)

RWAs and TMMFs digitize assets like real estate and financial products, enhancing liquidity and efficiency. TMMFs, such as BlackRock's BUIDL fund, provide blockchain-powered alternatives to traditional money market funds, offering stable returns, increased transparency, and greater accessibility.

TradFi with Python

I. Risk Analytics

The most important risk statistics (alpha, betas, average return, standard deviation, sharp ratio, information ratio, value at risk, conditional value at risk, drawdown, turnover) will be discussed and implemented in Python. These risk analytics serve as a solid foundation for benchmarking the investment strategies in the upcoming sections.

II. Trading Strategies - Factor Investing, Smart Beta, Signals, Sorting

With the boom in technological advancements in trading and financial market applications, algorithmic trading is being welcomed and accepted by exchanges all over the world. Smart beta investing combines the benefits of passive investing and the advantages of active investing strategies. In the lecture, some Fama-French type quant factors (HML, SMB, MOM, VOL) will be implemented.

III. Portfolio Optimization

State-of-the-art portfolio optimization techniques have been proven popular in investment management. In a first step, the Mean-variance framework will be studied and enriched with various alternative specifications such as additional risk constraints, portfolio selection with higher moments, transaction costs, and robustness improvement methods via resampling. The optimization will be performed using SciPy which is a free and open-source Python library used for scientific computing.

Prerequisites: Knowledge of Python. Basic principles in Finance, Statistics, Probability theory, Optimization

Homework: Probably two take-home assignments which count for 50% of the overall grade. Group homework will be possible.

Exam: The final exam is to be taken in class.

Guest Lecture: One guest lecture from a practitioner in the Robo Advisor, Asset Management, or Hedge Fund Industry, whose content is fitting and complementary to what is covered in the lectures will be invited. Guest speakers might provide internship positions within their companies in Europe (or the US).

Upon successful completion of this course, each student will be able to:

Have a basic knowledge of DeFi. How to program and analyze trading strategies in Python. Understand the fundamentals of factor investing and its nuances. Optimize a portfolio with respect to some risk criteria using the SciPy framework. These acquired skills and techniques serve as a more than solid foundation for any entry job or internship within the financial industry (Fintech, Robo Advisory, Asset Manager, Hedge Funds, …)

Texts/Readings

Textbook:

- DeFi and the Future of Finance (Campbell R. Harvey, Ashwin Ramachandran and Joey Santoro)
- Yves Hilpisch - Python for Finance - Analyze Big Financial Data
- Fabozzi, Kolm, Pachamanova, Focardi - Robust Portfolio Optimization and Management
- Prigent - Optimization and Performance Analysis
- Qlan, Hua, Sorensen - Quantitative Equity Portfolio Management - Modern Techniques and Applications
- Scherer - Portfolio Construction and Risk Budgeting

Factors

- Fama, French - The Cross-Section of Expected Stock Returns - 1992
- Fama, French - Common risk factors in the returns on stocks and bonds – 1993
- Carhart - On Persistence in Mutual Fund Performance - 1997
- Fama, French - Profitability Investment & Avg Returns – 2006
- Frazzini, Pedersen - Betting Against Beta – 2013
- Novy-Marx, Velikov - Betting Against Betting Against Beta – 2018