Computational Finance Course

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Abstract

Course description:
The course aims at improving the student's knowledge of computational methods in the area of finance. Numerical algorithms and partial differential equations, in particular in the field of modeling asset prices and in option pricing are presented. The student learns to apply methods in a computer project.
Expected prior knowledge:
Basic knowledge of partial differential equations (PDEs), of numerical methods for solving PDEs, of linear algebra and of the basic of numerical linear algebra, computing tool: Python.

- Slides can be found here.
- The book used in the course can be get here here.
- Codes and the exercises for the book can be found here.
- Youtube Channel with courses can be found here.

1. Lecture 1- Introduction and Overview of Asset Classes

YouTube link: Lecture 01- https://youtu.be/IRMn6JQvU8A

1.1. Introduction
*1.2. *Background Knowledge, Materials for the course (book etc.)*
*1.3. *Outline of the Course*
*1.4. *Grading*
1.5. Financial Engineering
1.6. Financial Markets and Different Asset Classes
1.7. Stocks and Dividends
1.8. Interest Rates
1.9. Volatility
1.10. Options & Payoffs

2. Lecture 2- Stock, Options and Stochastics

YouTube link: Lecture 02- https://youtu.be/_8GUNJZwAQ0

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2.1. Trading of Options and Hedging
2.2. Commodities
2.3. Currencies and Cryptos
2.4. Value of Call and Put Options and Hedging
2.5. Modeling of Asset Prices and Randomness
2.6. Stochastic Processes for Stock Prices
2.7. Itô's Lemma for Solving SDEs

3. Lecture 3- Option Pricing and Simulation in Python

YouTube link: Lecture 03- https://youtu.be/MhmZaHWGWHc

3.1. Stock Paths and Simulation in Python
3.2. Black-Scholes model
3.3. Hedging with the Black-Scholes model
3.4. Martingales and Option Pricing
3.5. Coding of Martingales in Python
3.6. Risk Neutral Valuation and Feynman-Kac Formula
3.7. Measures and Impact on a Drift
3.8. Closed-Form Solution for Black-Scholes model

4. Lecture 4- Implied Volatility

YouTube link: Lecture 04- https://youtu.be/XKaBN-sgIA0

4.1. Key Elements for Pricing Derivatives
4.2. Black-Scholes Implied Volatility
4.3. Newton-Raphson Method and Implementation in Python
4.4. Time-Dependent Volatility Parameter, $\sigma(t)$
4.5. Implied Volatility Surface
4.6. Deficiencies of the Black-Scholes Model

5. Lecture 5- Jump Processes

YouTube link: Lecture 05- https://youtu.be/gLIb2SOoSXc

5.1. Inclusion of Jumps in the Stock Process
5.2. Poisson Process and Implementation in Python
5.3. Itô's Lemma and Jumps
5.4. Jumps and Asset Dynamics under the $\mathbb{Q}$-Measure
5.5. Partial Integro-Differential Equations
5.6. Different Jump Distributions and Implied Volatility
5.7. Expectation and Jump Processes
5.8. Characteristic Function for a Jump Process

6. Lecture 6- Affine Jump Diffusion Processes

YouTube link: Lecture 06- https://youtu.be/OJCBjGUyg2U

6.1. How to Choose a Pricing Method?
6.2. Fourier Transformation- Motivation
6.3. Characteristic Function for the Black-Scholes Model
6.4. Affine Diffusion Processes
6.5. Characteristic Function for High Dimensions
6.6. Affine Jump Diffusion Processes

7. Lecture 7- Stochastic Volatility Models

YouTube link: Lecture 07- https://youtu.be/HG3s2StHB3k

7.1. Towards Stochastic Volatility
7.2. The Stochastic Volatility Model of Heston
7.3. Correlated Stochastic Differential Equations
7.4. Ito's Lemma for Vector Processes
7.5. Pricing PDE for the Heston Model
7.6. Impact of SV Model Parameters on Implied Volatility
7.7. Black-Scholes vs. Heston Model
7.8. Characteristic Function for the Heston Model

8. Lecture 8- Fourier Transformation for Option Pricing

YouTube link: Lecture 08- https://youtu.be/qVqAeijw6aQ

8.1. Fourier Transformation
8.2. FFT- Fast Fourier Transformation in Python
8.3. The COS Method and Density Recovery
8.4. Implementation of the COS Method in Python
8.5. European Option Pricing with Characteristic Function
8.6. Pricing Experiments Using COS Method in Python

9. Lecture 9- Monte Carlo Simulation

YouTube link: Lecture 09- https://youtu.be/MJw1tg43uJE

9.1. Monte Carlo and Integration via Sampling
9.2. Examples of Stochastic Integrals in Python
9.3. Smoothness of a Payoff and Impact on Convergence
9.4. Types of Convergence
9.5. Option Pricing and Standard Error
9.6. Euler Discretization
9.7. Milstein Discretization

10. Lecture 10- Monte Carlo Simulation of the Heston Model

YouTube link: Lecture 10- https://youtu.be/c4XTHxpGP1g

10.1. Option Pricing with Monte Carlo
10.2. Simulation of the CIR Process
10.3. Exact Simulation of the CIR Model
10.4. Almost Exact Simulation of the Heston Model
10.5. The Heston Model and Simulation in Python

11. Lecture 11- Hedging and Monte Carlo Greeks

YouTube link: Lecture 11- https://youtu.be/pKFD6JWOJ5A

11.1. Hedging with the Black-Scholes Model
11.2. Dynamic Hedging- Python Experiment
11.3. Hedging with Jumps
11.4. Delta, Gamma and Vega Hedging
11.5. Monte Carlo Sensitivity: Finite Difference
11.6. Monte Carlo Sensitivity: Pathwise Sensitivities
11.7. Monte Carlo Sensitivity: Likelihood Ratio Method

12. Lecture 12- Forward Start Options and Model of Bates

YouTube link: Lecture 12- https://youtu.be/6MqOajy7rFs

12.1. Forward-Start Options
12.2. Characteristic Function for Pricing of Forward Start Options
12.3. Forward Start Options under the Black-Scholes Model
12.4. Forward Start Options under the Heston Model
12.5. Forward Implied Volatility with Python
12.6. The Bates Model
12.7. Variance Swaps

13. Lecture 13- Exotic Derivatives

YouTube link: Lecture 13- https://youtu.be/CNq9asJ_UkA

13.1. Overview of Payoffs in the Industry
13.2. Binaries and Digitals
13.3. Path-Dependent Options: Barrier Options
13.4. Asian Options
13.5. Multi-Asset Options

14. Lecture 14- Summary of the Course

YouTube link: Lecture 14- https://youtu.be/WkTewla837M

14.1. Summary of the Course