FRE 6931: Spc Tpcs: Algorithmic Differentiation and Adjoint Methods in Finance
SECTION — Spring 2022

Instructor Information

Name: Luca Capriotti
Email: luca.capriotti@gmail.com
Zoom Office Hours: By appointment

Class Information

Dates: TBC
Time: TBC
Classroom: Zoom

Special Dates

Dates when no class will be held will be specified at the start of the course.

Pre-requisites

Derivative Securities and Stochastic Calculus, or equivalent.

Course Description

This half semester course introduces Adjoint Algorithmic Differentiation (AAD) one of the principal innovations in risk management of the recent times, revolutionizing the way practitioners compute price sensitivities (the so-called 'Greeks') of derivatives portfolios and reducing by orders of magnitude the cost associated with their computation.

Despite being a well-established mathematical approach, the potential of Algorithmic Differentiation (AD) has remained largely untapped until very recently in many areas of natural and applied sciences. In particular, it has been only recently rediscovered in financial engineering where it has opened a new important chapter in risk management, by making possible the calculation of the risk borne by large portfolios of securities accurately, in real time and with limited computational costs, ultimately boosting profitability through better risk management practices.

Being a relatively recent development in financial engineering, AD and Adjoint Methods are still not generally part of Master of Financial Engineering curricula, and the aim of this course is to contribute to bridge this gap and provide a comprehensive and practical introduction to this topic.

The theory of AD will be discussed starting from simple, easy to understand, examples illustrating the workings of the different 'modes' of AD and the reason behind the remarkable computational efficiency of adjoint methods. Focus will be placed on its application to Monte Carlo methods for Stochastic Differential Equations and finite difference methods for Partial Differential Equations which will be reviewed putting emphasis on practical examples and applications. With several use cases, drawing from different asset classes both in Equities and Fixed Income, the course will illustrate the workings of AD and demonstrate how it can be straightforwardly implemented to reduce the computation time of the risk of any portfolio by order of magnitudes. Each example will be preceded by a self-contained and practical overview of the relevant option pricing theory/methods.

This course can be used as a complement to modules on numerical methods in financial engineering.

Course Requirements

There will be several assignments and one take-home final exam. Half the grade is based on the assignments; the other half is based on the final exam.

Slides

Slides and assignments can be downloaded from NYU Classes.

Reading Materials

Reading Materials: For the introductory material on Monte Carlo methods, P. Glasserman, Monte Carlo Methods in Financial Engineering. For the rest of the material, relevant research articles will be mentioned on a weekly basis.

Outline

1. Computing Risk in Monte Carlo
    - Option Pricing Problems
    - Monte Carlo Methods
    - Classical Methods for the Computation of Sensitivities
    - The Finite Difference Method
    - The Likelihood Ratio Method
    - The Pathwise Derivative Method
    - Algebraic Adjoint Approaches
2. Algorithmic Differentiation
    - Computational Graphs
    - Tangent Mode
    - Adjoint Mode (AAD)
    - Second Order Greeks
    - Case Study: Greeks for Basket Options
3. Implementation
    - AAD as a Design Principle
    - Automated Tool (Operator Overloading/Source Code Transformation)

4. AAD and Monte Carlo

   - AAD and the Pathwise Derivative Method
   - Case Study: Adjoint Greeks for the Libor Market Model
   - Correlation Greeks
   - Case Study: Correlation Risk for Basket Default Contracts
   - Case Study: Real Time Counterparty Credit Risk Management
   - Second Order Greeks
   - Payout Regularization

5. AAD and Partial Differential Equations (PDE)

   - Option Pricing and PDEs
   - Discretization of Forward and Backward parabolic PDEs
   - Adjoint Forward parabolic PDEs
   - Adjoint Backward parabolic PDEs

6. AAD and Calibration

   - Calibration problems
   - Implicit Function Theorem
   - AAD and the Implicit Function Theorem
   - Case Study: Calibration of Interest Rate and Default Intensity short-rate models

Inclusion Statement

The NYU Tandon School values an inclusive and equitable environment for all our students. I hope to foster a sense of community in this class and consider it a place where individuals of all backgrounds, beliefs, ethnicities, national origins, gender identities, sexual orientations, religious and political affiliations, and abilities will be treated with respect. It is my intent that all students' learning needs be addressed both in and out of class and that the diversity that students bring to this class be viewed as a resource, strength, and benefit. If this standard is not being upheld, please feel free to speak with me.