TRAINING PROGRAM

The training includes 2 skill units in Financial Engineering:

1. Fundamental tools and methods.
2. Advanced applications.

SKILL UNIT 1 : FUNDAMENTAL TOOLS AND METHODS

Module 1: Stochastic modeling and derivatives delivered by Emmanuel Gobet, Professor at Ecole Polytechnique

Objective: Master the up-to-date tools for stochastic modeling used in pricing/hedging derivatives, calibratiing models, managing and modeling risks.

Content :

- Financial derivatives, future and forward contracts, spot markets, no-arbitrage arguments, static hedging of vanilla options with call/puts
- Dynamics hedging portolio, change of numeraire, PDE valuation, Black-Scholes formula and ramifications
- Local and stochastic volatility, Dupire model, Heston model, Gyongy projection
- Implied volatility, dynamics of IV, links with spot volatility, hedging and sticky rules, robustness formulas
- Asymptotics for prices and implied volatility (small maturity, small vol of vol, large strikes, wing's formula…)
- Interest rates modeling, HJM framework, Gaussian model, market models
- FX markets, cross-currency derivatives

Evaluation: written final exam + pricing/calibration project joint with "Numerical methods".

Acquired skills :

In-depth understanding of stochastic models dynamics of traded assets, inetrest rates, etc, and their use for the pricing of derivative products and risk management.

Module 2: Numerical methods: efficient Monte Carlo by Gilles Pages, Professor at Sorbonne Université

Objective: Provide fast efficient simulation methods for pricing and hedging derivatives on various asset classes, risk management, model validation.

Content :

- Random variate simulation: yield and complexity
- Variance reduction
- Numerical schemes for stochastic dynamics : which scheme for which problem
- Quasi-Monte Carlo versus Monte Carlo
- Erasing the bias: multilevel mehods
- Efficient implémentation on modern device (GPU)

Evaluation: written final exam + computing project joint with « Stochastic Calculus & Control or Derivatives.

Acquired skills:

Optimize the implementation of a Monte Carlo simulation method under operational constraints.

Module 3: Statistical Methods and Data Science for Finance by Mathieu Rosenbaum, Professor at Ecole Polytechnique

Objective: Introduction to standard statistical methods for risk management.

Content :

- Markowitz theory and capital asset pricing model
- Principal component analysis
- Random matrices
- High dimensional regression methods
- Copulas
- GARCH models

Evaluation: Take home QCM + computing project joint with « Derivatives".

Acquired skills:

- Estimation techniques for portfolio management, Econometrics of high dimensional data
- Risk modelling and forecasting.

Module 4: Stochastic calculus and control theory by Nizar Touzi, Professor at Ecole Polytechnique

Objective : Basics of stochastic calculus tools for finacial modeling, Hamilton-Jacobi-Bellman equations for control problems, applications in hedging and portfolio optimization.

Content :

- Brownian motion, stochastic integral, Itô's formula, Girsanov's change of measure, review of basic valuation theory, Poisson process, financial modeling with jumps
- Optimal stochastic control and HJB equation, application to portfolio optimization
- Optimal stopping and obstacle partial differential equation, applcation to American securities
- Introduction to stochastic differential games, application to contract theory

Evaluation: Take home QCM + computing project joint with « Numerical methods".

Acquired skills: Stochastic modeling, optimization under uncertainty, nonlinear partial differential equations.

SKILL UNIT 2: ADVANCED APPLICATIONS

Module 1: Stochastic control and incomplete markets, by Idris Kharroubi, Professor at Sorbonne University

Objective: Introduction to the study of discrete-time models specific to certain financial markets

Content :

- Controlled Markov chains
- Dynamic programming
- Calculation of optimal values and optimal controls

- Reliability
- Savings/consumption trade-off
- Optimal stop
- Energy management

Evaluation: Project.

Skills acquired: Implementation of a model relating to a given practical problem. Implementation and calculation of optimal strategies and values.

Module 2 : High Frequency and Algorithmic Trading by Charles Albert Lehalle, Senior Researcher at CFM, Mathieu Rosenbaum, Professor at Ecole Polytechnique and Sophie Laruelle

Objective: Introduction to cutting edge statistical and stochastic control techniques for high frequency finance under the new regulatory environment.

Content :

- Market microstructure after MIFID II
- Introduction to high frequency modelling
- High frequency statistics
- Limit order book modelling
- Optimal high frequency trading
- Microstructure and volatility
- Regulatory issues

Evaluation: written examination + project (joint with other courses).

Acquired skills: Master the principles, models and techniques of High Frequency and Algorithmic Trading in connection with the evolution of the regulation.

Module 3 : Energy Markets by Olivier Bardou ENGIE & Sorbonne Université, René Aïd, Professor at Dauphine

Objective: Introduction to the specificities of energy markets and to the mathematical tools.

Content :

- Modeling of energy markets (gas, oil, electricity) : spcificities and mathematical tools. (stochastci convolutions, jump diffusions)
- Dynamics of the underlying: spot prices , forward price structure, correlations,
- Derivative contracts (swing option, sparks options, real options)
- More about gas (gas plants, storage, take-or-pay contracts)
- More about electricity (peaks, negative prices, etc)
- Stochastic control methods for pricing energy derivatives : theoreticaal and numerical apsects.

Evaluation: written examination.

Acquired skills :

- Master the principle of modelling of assets and the pricing of spot/forward contracts on energy markets (especially gas and electricity).

Module 4 : Fintech/Retail finance by Sébastien Choukroun, PwC

Objective: Basic notions of machine learning.

Content :

- Introduction to cryptography
- Tokenisation of asset by blockchain, bitcoin
- Blockchain by ethereal, smart contracts
- Ledger (securisation of crypto-currency)
- Examples of use case

Evaluation: analysis of a use case.

Acquired skills: Understand the basics of blockchain technology and how to use it for crypto-currencies with a focus on use case.

Module 5 : Machine Learning by Victor Reutenauer, Director at Fotonower et Gilles Pagès, Professor at Sorbonne Université

Objective: Basic notions of machine learning.

Content:

- Supervised and unsupervised learning
- Regression, classification
- Recommendation and e-marketing
- Tools for convex optimization, online stochastic optimization

Evaluation: written examination and/or project (shared with other courses).

Acquired skills: Master the basics from supervised and unsupervised in order to use the main plateforms recently released like tensorflow, pytorch, etc, in view of financial application.