STAR/PWN/FWO

22nd Winter School on Mathematical Finance

Special topics:

Quantum computing for quantitative finance

Knightian uncertainty

January 20–22, 2025
Conference Hotel Kontakt der Kontinenten, Soesterberg

Sponsored by STAR, PWN and FWO

Winter School on Mathematical Finance

In recent years, the mathematical theory associated with financial risk management and the pricing of contingent claims has been a highly active field of research. The area has established itself as one of the most vigorously growing branches of applied mathematics. Model-based analysis of contracts and portfolios has become a standard in the finance industry, and the number of academic institutions offering curricula in financial mathematics has increased rapidly. In this context, the winter school on Mathematical Finance that will take place on January 20–22, 2025 in Soesterberg aims at providing a meeting place for participants both from industry and from academia. The program provides ample opportunity for discussion.

The special topics of the 22nd winter school are *Quantum computing for quantitative finance*, and *Knightian Uncertainty*. These are the subjects of minicourses that will be taught by two distinguished speakers: Professors Antoine Jacquier (Imperial College) and Frank Riedel (University of Bielefeld). Additionally there will be three one-hour special invited lectures by Professors Zorana Grbac (Université Paris-Diderot), Birgit Rudloff (Vienna University of Economics and Business) and Sara Svaluto-Ferro (University of Verona). Thirty-minute lectures on recent research work in the Netherlands will be presented by Kristoffer Andersson (Utrecht University), Balint Negyesi (Delft University of Technology), Zhipeng Huang (Utrecht University) and Jasper Rou (Delft University of Technology).

Auspices, sponsoring and grants

The Winter School takes place under the auspices of the mathematics cluster STAR and of PWN. The stochastics groups of the mathematics departments of the universities in the Netherlands cooperate in STAR. PWN (Platform Wiskunde Nederland) is a national organization that aims to strengthen the position of mathematics in the Netherlands in all its aspects. The winter school is supported financially by STAR, PWN, and by the Research Foundation - Flanders (FWO). Administrative assistance is provided by the Korteweg–De Vries Institute for Mathematics of the University of Amsterdam. Financial support by NWO is under consideration at the time of writing.

The FWO research network *Modelling and Simulation with applications in Finance, Insurance and Economics* has made available a limited number of grants for young researchers (PhD students and postdocs) associated to the network to be used as a waiver for the registration fee for the winter school. For other young researchers a limited number of grants of € 250 each is available as a reduction on the registration fee for the winter school. Priority will be given to grant applications from PhD students whose supervisor is a member of the network, but others are invited to apply as well.

Applications for the grant can be sent by email to both Michel Vellekoop and Asma Khedher (make sure both are addressed, a.khedher@uva.nl and m.h.vellekoop@uva.nl). Applications are required to contain a brief motivation why the grant should be beneficial for the research of the applicant, a brief motivation why the applicant has a specific need for the grant, a (link to a) CV of the applicant and the name of her/his principal supervisor. Applications should be submitted before the deadline, November 20, 2024.

Organizers

The winter school is organized by:

Michel Vellekoop (Faculty Economics and Business, University of Amsterdam; tel. +31 20 5254210, e-mail m.h.vellekoop@uva.nl),

Asma Khedher (Korteweg–De Vries Institute for Mathematics, University of Amsterdam; tel. +31 20 5258221, e-mail a.khedher@uva.nl).

Program outline

The program starts with registration and coffee on Monday, January 20, from 10:30 to 11:30, and ends on Wednesday, January 22, at 16:00. The following events are planned:

Minicourses

Antoine Jacquier
Quantum computing for quantitative finance

Frank Riedel
Knightian uncertainty

Special invited lectures

Zorana Grbac
Modeling of overnight and term interest rates after the Libor transition

Birgit Rudloff
Term structure modelling beyond stochastic continuity

Sara Svaluto-Ferro
Tractable infinite dimensional models: theory and applications

Short contributions

Kristoffer Andersson
Robust deep FBSDE methods

Zhipeng Huang
Generalized convergence for the deep BSDE method

Balint Negyesi
A deep BSDE approach for the simultaneous pricing and delta-gamma hedging of large portfolios consisting of high-dimensional multi-asset Bermudan options

Jasper Rou
A time-stepping deep gradient flow method for option pricing

Schedule of lectures

	Monday January 22	Tuesday January 23	Wednesday January 24
09:00 - 10:00		Jacquier	Jacquier
10:30 - 11:30		Jacquier	Jacquier
11:30 - 12:30	Jacquier	Riedel	Riedel
14:00 - 15:00			Riedel
15:00 - 16:00	Riedel	Riedel	Grbac
16:00 - 17:00	Rudloff	Svaluto-Ferro	
17:30 - 18:00	Andersson	Huang	
18:00 - 18:30	Negyesi	Rou	

Venue

The winter school will take place in Conference Hotel Kontakt der Kontinenten, Amersfoortsestraat 20, 3769 AS Soesterberg, phone: +31 (0) 346 35 17 55. Located in the heart of the country, Kontakt der Kontinenten is one of the top accommodations in the Netherlands in terms of attractiveness of surroundings. Access by car or by public transportation is easy. By train, one can reach the city of Amersfoort, and then proceed from the station by bus (about 15 minutes, Bus 34 or Bus 56). See https://9292.nl/en for planning public transportation, use `Kontakt der Kontinenten` as the destination. Typically, from Schiphol (Amsterdam Airport) it takes 70–80 minutes for the complete journey. The bus stop is in front of the hotel (see directions on the webpage below). If you come by car, it is best to use a modern navigator. It is also possible to take a taxi from the taxi stand at railway station Amersfoort. For further details, please see https://www.kontaktderkontinenten.nl/en or Google maps (search for `Kontakt der Kontinenten`).

Website

https://staff.fnwi.uva.nl/a.khedher/winterschool/winterschool.html

Abstracts

Minicourse I

Antoine Jacquier (Imperial College)

Quantum computing for quantitative finance

Quantum Computing, relegated for decades as a spooky distant myth, is now becoming a reality. To wit, quantum computers (albeit small in scale) are already available, developed by the likes of IBM, Rigetti, D-Wave, Google, Microsoft, ... However, a quantum computer is not simply a bigger and more powerful computer, and requires a whole new set of algorithms to be written to perform useful tasks. These, and the underlying technology, draw from the laws of quantum mechanics, are fundamentally different from our usual numerical toolbox. The goal of this course is to provide a mathematical introduction to Quantum Computing and to highlight applications in Quantitative Finance, in particular for Monte Carlo simulations, machine learning and optimisation. Numerical examples (through python) will also be introduced to provide a tangible reality.

Minicourse II

Frank Riedel (University of Bielefeld)

Knightian uncertainty

Knightian uncertainty has emerged as a major research topic in recent years. Frank Knight's pioneering dissertation on "Risk, Uncertainty, and Profit" distinguishes risk—a situation that allows for an objective probabilistic description—from uncertainty - a situation that cannot be modeled by a single probability distribution. By now, it is widely acknowledged that such Knightian uncertainty is crucial in many fields, including financial markets, climate economics, and pandemics. The lectures introduce the main decision-theoretic models that have been developed. Applications to finance (risk measures and management, absence of arbitrage, robust portfolio choices) and economics (viability and equilibrium, game theory, mechanism design, climate change) are discussed in detail.

Special invited lectures

Zorana Grbac (Université Paris-Diderot)

Modeling of overnight and term interest rates after the Libor transition

In the recent reform of interbank interest rates the classical term rates such as Libor were discontinued and the overnight risk-free rates (RFRs) such as the secured overnight financing rate (SOFR) are now taking the lead role. Pertinent modelling of overnight rates and constructing of term rates have become major challenges in fixed income theory and practice. In this talk I would like to give some insights into these issues and present a modeling framework taking them into account. Firstly, I will give a brief overview of the reform and introduce the main modeling quantities. One of the key features of overnight rates is the presence of jumps and spikes occurring at predetermined dates which are caused by monetary policy interventions and liquidity constraints. These jumps correspond to the so-called stochastic discontinuities in the stochastic processes driving the dynamics of the rates. Next, I will discuss the way the forward term rates are produced in the market and the discrepancy between the theoretical term rates generated by overnight rates and the market term rates. We provide a mathematical model of this situation and propose a general framework in which the dynamics of the forward term rates are described via BSDEs with a given terminal condition. In a tractable setup based on affine semimartingales with stochastic discontinuities we study these BSDEs which in general may admit multiple solutions and provide sufficient conditions ensuring uniqueness. This reflects precisely the current market environment and allows for its better understanding and analysis. The resulting modeling framework is a Heath-Jarrow-Morton (HJM) generalized framework incorporating possible stochastic discontinuities in the dynamics of overnight and term rates. In particular, when the term rate is generated by the overnight rate itself, we show that it solves a BSDE, whose driver is determined by the HJM drift restrictions.

In the concluding part of the talk, I will present some simple specifications focusing on the overnight rate and illustrate pricing and hedging of interest rate derivatives in the presence of stochastic discontinuities.
(Based on joint works with C. Fontana, S. Gümbel and T. Schmidt.)

Birgit Rudloff (Vienna University of Economics and Business)

Epic Math Battles: Nash vs Pareto

Nash equilibria and Pareto optimization are two distinct concepts in multi-criteria decision making. It is well known that the two concepts do not coincide. However, in this work we show that it is possible to characterize the set of all Nash equilibria for any non-cooperative game as the set of all Pareto optimal solutions of a certain vector optimization problem. The characterization holds for all non-cooperative games (non-convex, convex, linear).

This characterization opens a new way of computing Nash equilibria. It allows to use algorithms from vector optimization to compute resp. to approximate the set of all Nash equilibria, which is in contrast to the classical fixed point iterations that find just a single Nash equilibrium. This computation is straight forward in the linear case. In this talk we will discuss recent results in the convex case. An algorithm is proposed that computes for a given error distance epsilon, a subset of the set of epsilon-Nash equilibria such that it contains the set of all (true) Nash equilibria for convex games with either independent convex constraint sets for each player, or polyhedral joint constraints.

Sara Svaluto-Ferro (University of Verona)

Tractable infinite dimensional models: theory and applications

During this course we introduce, study, and apply several stochastic models in infinite dimensions. We focus in particular to the class of infinite dimensional polynomial (jump-) diffusions, for which a set of ready-to-use mathematical tools have been developed. The first part of the course is dedicated to the theoretical aspects. After a presentation of the martingale problem we move to the so-called moment formula, providing a representation of some expected quantities in terms of an infinite dimensional linear ODE. In some cases of interest such ODE reduces to a PDE, has a representation à la Feyman-Kac, or can even be solved explicitly, for some or all initial conditions. In the second part we study two main applications: measure valued diffusions for energy markets and signature models in finance. We introduce a framework that allows to employ (non-negative) measure-valued processes for energy market modeling, in particular for electricity and gas futures. Interpreting the process' spatial structure as time to maturity, we show how the Heath-Jarrow-Morton (HJM) approach can be translated to this framework, thus guaranteeing arbitrage free modeling in infinite dimensions. We derive an analog to the HJM-drift condition and then treat in a Markovian setting existence of non-negative measure-valued diffusions that satisfy this condition. To analyze mathematically convenient classes we consider measure-valued polynomial and affine diffusions, where we can precisely specify the diffusion part in terms of continuous functions satisfying certain admissibility conditions. For calibration purposes, we illustrate how these functions can then be parameterized by neural networks yielding measure-valued analogs of neural SPDEs. By combining Fourier approaches or the moment formula with stochastic gradient descent methods, this then allows for tractable calibration procedures which we also test by way of example on market data. Finally, we introduce the concept of signature of a semimartingale and present its main properties. In particular, we show that the signature process of a (classical) polynomial process is a polynomial process and illustrate how the moment formula applies in this case. We then move to signature SDEs whose characteristics are linear functions of a primary underlying process, which can range from a (market-inferred) Brownian motion to a general multidimensional tractable stochastic process.

Short contributions

Kristoffer Andersson (University of Verona)

Robust deep FBSDE methods

The deep BSDE method and its extensions have brought significant progress in approximating PDEs and FBSDEs, particularly in high-dimensional settings. However, the method fails to converge for a large class of important problems. This presentation aims to provide the audience with an intuitive understanding of when and why the deep BSDE method encounters convergence issues. A focus will be placed on the class of FBSDEs arising from stochastic optimal control problems, discussing how mathematical structures from control theory can be utilized to adjust the deep BSDE method, ensuring convergence. Additionally, potential adjustments for general FBSDEs, where connections to stochastic control are absent, will be explored. The goal is to share insights into the theoretical aspects and practical implementations of these approaches, extending the applicability of the deep BSDE method to a broader range of problems.

Zhipeng Huang (Utrecht University)

Generalized convergence for the deep BSDE method

We are concerned with high-dimensional coupled FBSDE systems approximated by the deep BSDE method of Han et al. (2018). It was shown by Han and Long (2020) that the errors induced by the deep BSDE method admit a posteriori estimate depending on the loss function, whenever the backward equation only couples into the forward diffusion through the Y process. We generalize this result to fully-coupled drift coefficients, and give sufficient conditions for convergence under standard assumptions. The resulting conditions are directly verifiable for any equation. Consequently, our convergence analysis enables the treatment of FBSDEs stemming from stochastic optimal control problems. In particular, we provide a theoretical justification for the non-convergence of the deep BSDE method observed in recent literature, and present direct guidelines for when convergence can be guaranteed in practice. Our theoretical findings are supported by several numerical experiments in high-dimensional settings.
(This is a joint work with Balint Negyesi and Cornelis W. Oosterlee.)

Balint Negyesi (Delft University of Technology)

A deep BSDE approach for the simultaneous pricing and delta-gamma hedging of large portfolios consisting of high-dimensional multi-asset Bermudan options

Direct financial applications of the methods introduced in Negyesi et al. (2024), Negyesi (2024) are presented. Therein, a new discretization of (discretely reflected) Markovian backward stochastic differential equations is given which involves a Gamma process, corresponding to second-order sensitivities of the associated option's price. The main contributions of this work is to apply these techniques in the context of portfolio risk management. Large portfolios of a mixture of European and Bermudan derivatives are cast into the framework of discretely reflected BSDEs. The resulting system is solved by a neural network regression Monte Carlo method proposed in the aforementioned papers. Numerical experiments are presented on high-dimensional portfolios, consisting of several European, Bermudan and American options, which demonstrate the robustness and accuracy of the method. The corresponding Profit-and-Loss distributions indicate an order of magnitude gain in the number of rebalancing dates needed in order to achieve a certain level of risk tolerance, when the second-order conditions are also satisfied. The hedging strategies significantly outperform benchmark methods both in the case of standard delta- and delta-gamma hedging.

Jasper Rou (Delft University of Technology)

A time-stepping deep gradient flow method for option pricing

In this research, we consider a novel deep learning approach for pricing options by solving partial differential equations (PDE). More specifically, we consider a Time-stepping Deep Gradient Flow method, where the PDE is solved by discretizing it in time and writing it as the solution of minimizing a variational problem. A neural network approximation is then trained to solve this minimization using stochastic gradient descent. This method reduces the training time compared to for instance the Deep Galerkin Method. The proposed scheme respects the asymptotic behavior of option prices for large levels of moneyness and adheres to known bounds for option prices. The accuracy and efficiency of the proposed method is assessed in a series of numerical examples, with particular focus in the lifted Heston model. Furthermore, we prove two things. First, that there exists a neural network converging to the solution of the

PDE. This proof consists of three parts: 1) convergence of the time stepping; 2) equivalence of the solution of the discretized PDE and the minimizer of the variational formulation and 3) the approximation of the minimizer by a neural network by using a version of the universal approximation theorem. Second, we prove that when training the network we converge to the correct solution. This proof consists of two parts: 1) as the number of neurons goes to infinity we converge to some gradient flow and 2) as the training time goes to infinity this gradient flow converges to the solution.

Registration

To register for the winter school, please use the electronic registration form that is available at the web page of the winter school (see https://staff.fnwi.uva.nl/a.khedher/winterschool/winterschool.html).

The registration fee includes accommodation (single room) for the nights of January 20-21 and January 21-22, all meals starting with lunch on Monday up to and including lunch on Wednesday, and tea and coffee during breaks. Payment can be made by transfer to IBAN account number: NL27 INGB 0007388994 of Winter School Amsterdam, Secretariaat Korteweg–De Vries Instituut, Amsterdam and (for international money transfers) BIC: INGBNL2A.

The fee schedule is as follows:

	early registration (before December 1)	late registration (after December 1)
industry professional	€1395	€1650
full-time academic	€595	€650

Inquiries concerning fees for partial attendance may be directed to secr-kdv-science@uva.nl. Registration will be valid after full payment has been received. Refunds can be given only for cancellations received before January 1, 2025.

Please note that PhD students and postdocs which receive an FWO WOG grant should still register at the website, to ensure accommodation. You can mention "FWO WOG Grant" in the field "Remarks".

Accommodation at the venue is limited. Therefore, reservations will be treated on a first-come-first-served basis with priority for full arrangements. Participants who cannot be lodged at the venue will be accommodated in a hotel nearby. Transportation from the hotel to the venue and vice versa will be taken care of by the organization.

Further information

For further information regarding the scientific program, please contact one of the members of the organizing committee. For information concerning registration please contact:

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