STAR/PWN

21st Winter School on Mathematical Finance

Special topics:

Robust risk management

Signatures in finance

January 22–24, 2024
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 22–24, 2024 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 21st winter school are *Robust risk management*, and *Signatures in finance*. These are the subjects of minicourses that will be taught by two distinguished speakers: Professors Carole Bernard (Grenoble Ecole de Management and Vrije Universiteit Brussel) and Christa Cuchiero (University of Vienna). Additionally there will be three one-hour special invited lectures by Professors Griselda Deelstra (Université libre de Bruxelles), Claudio Fontana (University of Padova) and Antonis Papapantoleon (Delft University of Technology). Thirty-minute lectures on recent research work in the Netherlands will be presented by Kristoffer Andersson (Utrecht University), Jori Hoencamp (University of Amsterdam), Thomas van der Zwaard (Utrecht University and Rabobank) and Evgenii Vladimirov (University of Amsterdam).

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.

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 of the registration fee for the winter school. For those researchers the grants completely cover the registration fee. For other young researchers a limited number of grants of € 300 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, 2023.

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 22, from 10:30 to 11:30, and ends on Wednesday, January 24, at 16:00. The following events are planned:

Minicourses

Carole Bernard
Robust risk management

Christa Cuchiero
Signatures in finance

Special invited lectures

Griselda Deelstra
Some topics related to stochastic mortality and/or interest rates in the valuation of life insurance products

Claudio Fontana
Term structure modelling beyond stochastic continuity

Antonis Papapantoleon
Model-free and data driven methods in mathematical finance

Short contributions

Kristoffer Andersson
Convergence of a robust deep FBSDE method for stochastic control

Jori Hoencamp
A static replication approach for callable interest rate derivatives: Efficient estimation of forward prices and SIMM-MVA

Evgenii Vladimirov
Estimating option pricing models using a characteristic function-based linear state space representation

Thomas van der Zwaard
Valuation adjustments with an affine-diffusion-based interest rate smile

Schedule of lectures

	Monday January 22	Tuesday January 23	Wednesday January 24
09:00 - 10:00		Cuchiero	Cuchiero
10:30 - 11:30		Cuchiero	Cuchiero
11:30 - 12:30	Cuchiero	Bernard	Bernard
14:00 - 15:00			Bernard
15:00 - 16:00	Bernard	Bernard	Deelstra
16:00 - 17:00	Fontana	Papapantoleon	
17:30 - 18:00	Hoencamp	van der Zwaard	
18:00 - 18:30	Vladimirov	Andersson	

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

Carole Bernard (Grenoble Ecole de Management & Vrije Universiteit Brussel)

Robust Risk Management

Making sound decisions under uncertainty generally requires quantitative analysis and the use of models. However, a "perfect" model does not exist since some divergence between the model and the reality it attempts to describe cannot be avoided. In a broad sense, model risk is about the extent to which the quality of model-based decisions is sensitive to underlying model deviations and data issues. An example concerns the establishment of the capital buffers banks need to put aside to absorb unforeseen losses for a portfolio of risky loans. Doing so requires accurate estimates of the likelihood that various obligors default together, which is very difficult due to a scarcity of data.

We will discuss various approaches on how to plan for worst-case scenarios in a financial and insurance context. More specifically, we will discuss the problem of quantifying model uncertainty, such as departures from assumed independence, incomplete dependence information, factor models that are only partially specified, or portfolio information that is only available on an aggregate level (e.g., mean and variance of the portfolio loss), desired properties (e.g., unimodality, symmetry, non-negativity). We will develop necessary tools to quantify this model uncertainty and in particular to determine the best upper and lower risk bounds for various risk aggregation functionals of interest including Value-at-Risk, Range Value-at-Risk and distorted risk measures.

Minicourse II

Christa Cuchiero (University of Vienna)

Signature methods in finance

Signature methods represent a non-parametric way for extracting characteristic features from time series data which is essential in machine learning tasks. This explains why these techniques become more and more popular in Econometrics and Mathematical Finance. Indeed, signature based approaches allow for data-driven and thus more robust model selection mechanisms, while first principles like no arbitrage can still be easily guaranteed.

In this course we shall focus on the use of signature as universal linear regression basis of continuous functionals of paths for financial applications. We first give a brief introduction to continuous rough paths and show how to embed continuous semimartingales into the rough path setting. Indeed our main focus lies on signature of semimartingales, one of the main modeling tools in finance. By relying on the Stone-Weierstrass theorem we show how to prove the universal approximation property of linear functions of the signature in appropriate topologies on path space.

In the financial applications that we have in mind one key quantity that one needs to compute is the expected signature of some underlying process. Surprisingly this can be achieved for generic classes of diffusions, called signature-SDEs (with possibly path dependent characteristics), via techniques from affine and polynomial processes. More precisely, we show how the signature process of these diffusions can be embedded in the framework of affine and polynomial

processes. These classes of processes have been – due to their tractability – the dominating process class prior to the new era of highly over-parametrized dynamic models. Following this line we obtain that the infinite dimensional Feynman-Kac PDE of the signature process can generically be reduced to an infinite dimensional ODE either of Riccati or linear type.

In terms of financial applications, we shall treat two main topics: stochastic portfolio theory and signature based asset price models.

In the context of stochastic portfolio theory we introduce a novel class of portfolios which we call linear path-functional portfolios. These are portfolios which are determined by certain transformations of linear functions of a collections of feature maps that are non-anticipative path functionals of an underlying semimartingale. As main example for such feature maps we consider signature of the (ranked) market weights. Relying on the universal approximation theorem we show that every continuous (possibly path-dependent) portfolio function of the market weights can be uniformly approximated by signature portfolios. Besides these universality features, the main numerical advantage lies in the fact that several optimization tasks like maximizing expected logarithmic utility or mean-variance optimization within the class of linear path-functional portfolios reduce to a convex quadratic optimization problem, thus making it computationally highly tractable. We apply our method to real market data, indicating out-performance on the considered out-of-sample data even under transaction costs. In view of asset price models we consider a stochastic volatility model where the dynamics of the volatility are described by linear functions of the (time extended) signature of a primary underlying process, which is supposed to be some multidimensional continuous semimartingale. Under the additional assumption that this primary process is of polynomial type, we obtain closed form expressions for the VIX squared, exploiting the fact that the truncated signature of a polynomial process is again a polynomial process. Adding to such a primary process the Brownian motion driving the stock price, allows then to express both the log-price and the VIX squared as linear functions of the signature of the corresponding augmented process. This feature can then be efficiently used for pricing and calibration purposes. Indeed, as the signature samples can be easily precomputed, the calibration task can be split into an offline sampling and a standard optimization. For both the SPX and VIX options we obtain highly accurate calibration results, showing that this model class allows to solve the joint calibration problem without adding jumps or rough volatility.

Special invited lectures

Griselda Deelstra (Université libre de Bruxelles)

Some topics related to stochastic mortality and/or interest rates in the valuation of life insurance products

As a first topic, we study valuations of a class of hybrid life products which are related to both mortality and financial risks, assumed to be independent. In the presence of stochastic interest rates, we present a generalized standard deviation premium principle, and integrate it in different valuation operators suggested in the literature. We illustrate our methods with a classical application, namely a Pure Endowment with profit.
As a second topic, we focus on the relaxation of the traditional assumption of independence between mortality risk and interest rate risk. We investigate the impact of the inclusion of correlation on the best estimate of usual life insurance contracts and study in which cases the non-taking into account of correlation can lead to underestimations of the best estimate, and where one could have hedging possibilities in the presence of correlation. Therefore, we first present a framework of two correlated Hull and White processes for modelling the stochastic mortality and interest rates; and afterwards, we focus upon some alternative models.
(This talk is based on joint work with Pierre Devolder, Pieter Hieber, Oussama Belhouari, Benjamin Roelants du Vivier.)

Claudio Fontana (University of Padova)

Term structure modelling beyond stochastic continuity

Overnight rates, such as the Secured Overnight Financing Rate (SOFR), are central to the current reform of interest rate benchmarks. A striking feature of overnight rates is the presence of jumps and spikes occurring at predetermined dates due to monetary policy interventions and liquidity constraints. This corresponds to stochastic discontinuities (i.e., discontinuities occurring at ex ante known points in time) in their dynamics. In this work, we propose a generalized Heath-Jarrow-Morton (HJM) setup allowing for stochastic discontinuities and characterize absence of arbitrage. We extend the classical short-rate approach to accommodate stochastic discontinuities, developing a tractable setup driven by affine semimartingales. In a Gaussian setting, we provide explicit valuation formulas for bonds and caplets. Furthermore, we investigate hedging in the sense of local risk-minimization when the underlying term structures feature stochastic discontinuities. Time permitting, we shall explore applications beyond the interest rate setting. (Based on joint work with Z. Grbac and T. Schmidt.)

Antonis Papapantoleon (Delft University of Technology)

Model-free and data driven methods in mathematical finance

Academics, practitioners and regulators have understood that the classical paradigm in mathematical finance, where all computations are based on a single "correct" model, is flawed. Model-free methods, were computations are based on a variety of models, offer an alternative. More recently, these methods are driven by information available in financial markets. In this talk, we will discuss model-free and data driven methods and bounds and present how ideas from probability, statistics, optimal transport and optimization can be applied in this field.

Short contributions

Kristoffer Andersson (Utrecht University)

Convergence of a robust deep FBSDE method for stochastic control

In this talk, a deep learning based numerical scheme for strongly coupled FBSDEs is presented. More specifically, problems stemming from stochastic control problems are considered and the method is a modification of the deep BSDE method in which the initial value of the backward equation is not a free parameter, and with a new loss function being the weighted sum of the cost of the control problem, and a variance term which coincides with the mean squared error in the terminal condition. It is demonstrated by a numerical example that a direct extension of the classical deep BSDE method to FBSDEs, fails for a simple linear-quadratic control problem, and motivate why the new method works. Under regularity and boundedness assumptions on the exact controls of time continuous and time discrete control problems, an error analysis for our method is provided. Finally, empirical experiments demonstrate that the method converges for three different problems, one being the one that failed for a direct extension of the deep BSDE method.

Jori Hoencamp (University of Amsterdam)

A static replication approach for callable interest rate derivatives: Efficient estimation of forward prices and SIMM-MVA

The computation of credit risk measures such as exposure and Credit Valuation Adjustments (CVA) requires the simulation of future portfolio prices. Recent metrics, such as dynamic Initial Margin (IM) and Margin Valuation Adjustments (MVA) additionally require the simulation of future conditional sensitivities. For portfolios with non-linear instruments that do not admit closed-form valuation formulas, this poses a significant computational challenge. This problem is addressed by proposing a static replication algorithm for interest rate options with early-exercise features under an affine term-structure model. Under the appropriate conditions we can find an equivalent portfolio of vanilla options that replicate these products. Specifically we decompose the product into a portfolio of European swaptions. The weights and strikes of the portfolio are obtained by regressing the target option value with interpretable, feed-forward neural networks. Once an equivalent portfolio of European swaptions is determined, we can leverage on closed-form expressions to obtain the conditional prices and sensitivities, which serve as an input to exposure and SIMM- driven MVA quantification. For a consistent forward sensitivity estimation, this involves the differentiation of the portfolio-weights. The accuracy and convergence of the method is demonstrated through several representative numerical examples, benchmarked against the established least-square Monte Carlo method.

Evgenii Vladimirov (University of Amsterdam)

Estimating option pricing models using a characteristic function-based linear state space representation

We develop a novel filtering and estimation procedure for parametric option pricing models driven by general affine jump-diffusions. Our procedure is based on the comparison between an option-implied, model-free representation of the conditional log-characteristic function and the model-implied conditional log-characteristic function, which is functionally affine in the model's state vector. We formally derive an associated linear state space representation and

establish the asymptotic properties of the corresponding measurement errors. The state space representation allows us to use a suitably modified Kalman filtering technique to learn about the latent state vector and a quasi-maximum likelihood estimator of the model parameters, which brings important computational advantages. We analyze the finite-sample behavior of our procedure in Monte Carlo simulations. The applicability of our procedure is illustrated in two case studies that analyze S&P 500 option prices and the impact of exogenous state variables capturing Covid-19 reproduction and economic policy uncertainty. (Joint work with Peter Boswijk and Roger Laeven.)

Thomas van der Zwaard (Utrecht University and Rabobank)

Valuation adjustments with an affine-diffusion-based interest rate smile

Affine Diffusion (AD) dynamics are frequently used for Valuation Adjustments (xVA) calculations due to their analytic tractability. However, these models cannot capture the market-implied skew and smile, which are relevant when computing the xVA metrics. Hence, additional degrees of freedom are required to capture these market features. In this paper, we address this through an SDE with state-dependent coefficients. The SDE is consistent with the convex combination of a finite number of different AD dynamics. In this paper, we combine Hull-White one-factor (HW) models where one model parameter is varied. We use the Randomized AD (RAnD) technique to parameterize the combination of HW models. We refer to our SDE with state-dependent coefficients and the RAnD parametrization of the HW models as the rHW model. The rHW model allows for fast semi-analytic calibration to European swaptions through the analytic tractability of the HW dynamics. A regression-based Monte Carlo simulation is used to calculate exposures. In this setting, we assess the effect of skew and smile on exposures of interest rate derivatives.

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 22-23 and January 23-24, 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	€1325	€1575
full-time academic	€475	€525

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, 2024.

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:

The secretariat of the
Korteweg–De Vries Institute for Mathematics
University of Amsterdam
e-mail: secr-kdv-science@uva.nl
tel.: +31-(0)20-5255217