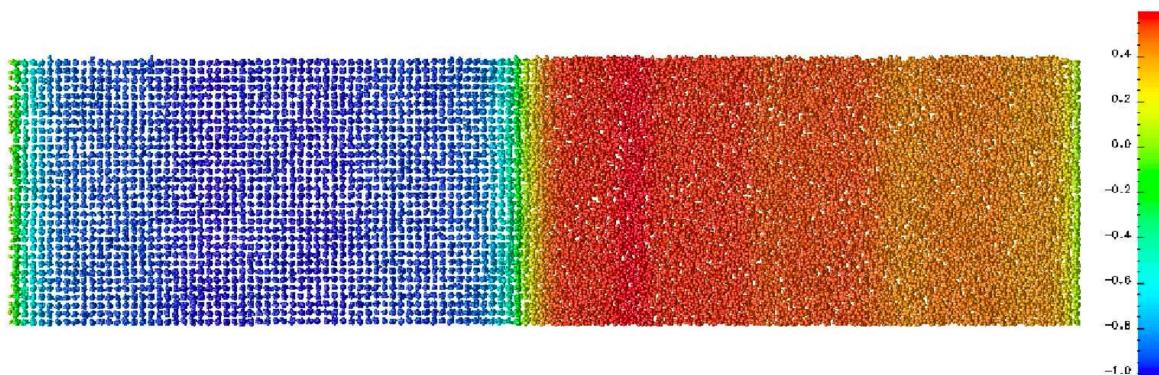


Welcome to the course Computational methods for stochastic differential equations and machine learning (joint SF2525 master level and SF3581 graduate level) 2020



OMX Stockholm 30 index för en dag, en månad och tre år, från Avanza.



Stochastic molecular dynamics of liquid-solid phase transition



The classical Spacewar game, emulated at <http://www.masswerk.at/spacewar/>

The course focuses on the following application areas and mathematical and numerical methods to solve them. In each application we study relevant mathematical and numerical methods to solve the problem. This includes methods and theory for ordinary, partial and stochastic differential equations, and optimal control, treating e.g. weak and strong approximation, Monte Carlo methods, variance reduction, large deviations for rare events, game theory, neural networks.

Applications included are e.g. finance, where stock prices are modelled using SDEs, molecular dynamics, where SDEs are used to model systems with constant temperature, and machine learning where the basic stochastic gradient descent algorithm is a numerical scheme for perturbed gradient flow. Optimal control theory is used e.g. in optimal hedging, finding reaction rates in molecular dynamics and analyzing machine learning convergence rates. The course includes computer projects using the machine learning software TensorFlow.

Week	Application	Subject
3,4,5	stocks with noise molecular dynamics	stochastic differential equations, weak and strong convergence, Ito-calculus
	AI	Euler's method
6,7,8,9	option price American options	The Feynman-Kac formula, Monte-Carlo Methods, variance reduction finite difference methods
12,13,15	optimal hedging reaction rates	calculus of variations, optimal control dynamical programming, Hamilton-Jacobi equations, large deviations and rare events
16,17,19	machine learning AI	game theory, differential games, neural networks, stochastic gradient descent
20	presentations e.g: multi-level Monte Carlo, ground water flow neural networks, AI	variance reduction, Convection-diffusion equations,

## Course material and evaluation

- New version of the [lecture notes \(https://canvas.kth.se/courses/17788/files?preview=2760616\)](https://canvas.kth.se/courses/17788/files?preview=2760616)
- Chapter 6 in ["An Introduction to Mathematical Optimal Control Theory \(https://math.berkeley.edu/~evans/control.course.pdf\)"](https://math.berkeley.edu/~evans/control.course.pdf) by L.C. Evans

- papers for the presentations are [here \(https://canvas.kth.se/courses/4143/files/\)](https://canvas.kth.se/courses/4143/files/)
- [course syllabus \(https://www.kth.se/student/kurser/kurs/SF2525\)](https://www.kth.se/student/kurser/kurs/SF2525)
- [course evaluation, use the code: random \(https://www.math.kth.se/cgi-bin/evaluation/evaluation?e=489\)](https://www.math.kth.se/cgi-bin/evaluation/evaluation?e=489)

## Teachers

Anders Szepessy, department of mathematics, [szepessy@kth.se](mailto:szepessy@kth.se) (<mailto:szepessy@kth.se>), office hour Mondays 12-13.

Aku Kammonen, department of mathematics, [kammo@kth.se](mailto:kammo@kth.se) (<mailto:kammo@kth.se>), office hour Tuesdays 12-13.

## Schedule

Starting Friday January 17th, 13.15-15.00 in room E33.

[Schedule for lectures \(https://se.timeedit.net/web/kth/db1/public01/ri102.html\)](https://se.timeedit.net/web/kth/db1/public01/ri102.html)

Preliminary plan, in addition guest a guest lecture, a tensor flow tutorial and a review

Lecture 1: chapter 1-2 Introduction and stochastic integral

Lecture 2: chapter 2, 3.1-3 Stochastic differential equations

Lecture 3: chapter 3.1, 3.4 Ito's formula and Stratonovich integrals

Lecture 4: chapter 4.2 Kolmogorov equations and Black-Scholes equation

Lecture 5: chapter 4.1-2 Black-Scholes equation and Feynman-Kac formula

Lecture 6: chapter 5.1 Option modelling and statistical error

Lecture 7: chapter 5.1-2 Statistical and time discretization errors

Lecture 8: chapter 6.1-2 American options and Lax equivalence theorem

Lecture 9: chapter 10 Machine learning ([notes \(https://canvas.kth.se/courses/17788/files?preview=2709820\)](https://canvas.kth.se/courses/17788/files?preview=2709820) and video in Media Gallery)

Lecture 10 (24/3): chapter 10 Tensor flow and video [Introduction to HW 4&5 \(https://canvas.kth.se/courses/17788/files/2725470/download?wrap=1\)](https://canvas.kth.se/courses/17788/files/2725470/download?wrap=1)



Lecture 11: chapter 8.1-2 Optimal control

Lecture 12: chapter 9 Rare events

Lecture 13: chapter differential games

Lecture 14: Guest lecture by Jonas Kiessling, [slides \(https://canvas.kth.se/courses/17788/files?preview=2827238\)](https://canvas.kth.se/courses/17788/files?preview=2827238)

Lecture 15: chapter 8.3 Hamilton-Jacobi PDE and Stochastic optimal control

## Homework, Computer Lab's , Presentations and Examination

**New setup due to the online restriction:**

The examination consists of three parts: *Homework problems, oral presentations and a written report based on the chosen project*. The homework problems are available here on the course www-page and each student hand in their own solution. The presentations are carried out by groups of two *students*. The written report, one per project, is supposed to describe the results related to the poster presentation and in addition relate to some of the theory learned related to the course. For instance stating and deriving a proof and commenting the relevance and assumptions. In case someone seems to not pass the course due to the report, there will be a possibility to revise the report or the homework. The **written report is due June 1st**.

The homework and the presentation gives maximal 35 credits together, with maximal 5 credits for each homework 1,2,3,5 and maximal 10 credits for the final presentation and homework 4. The maximal score for the written report is 60, and to pass the course you must obtain a total score, homework included, of approximately 60.

**Previous setup:**

The Examination consists of three parts: Homework problems, oral presentations and a written exam. The homework problems will be available here on the course www-page and each student hand in their own solution. The presentations are carried out by groups of two *students*. A substantial part of the written exam will be based on a [list of questions given here](https://canvas.kth.se/courses/17788/files?preview=2726373) . (<https://canvas.kth.se/courses/17788/files?preview=2726373>)

The maximal score for the written exam is 60, and to pass the course you must obtain a total score, homework included, of approximately 60. The homework and the presentation gives maximal 35 credits together, with maximal 5 credits for each homework 1,2,3,5 and maximal 10 credits for the final presentation and homework 4.


[.\(http://www.csc.kth.se/~szepessy/sde\\_teori\\_2008.pdf\)](http://www.csc.kth.se/~szepessy/sde_teori_2008.pdf).


## Homework and dates

**Homework 1** [.\(http://www.nada.kth.se//kurser/kth/2D1269/h1.pdf\)](http://www.nada.kth.se//kurser/kth/2D1269/h1.pdf) on Ito integrals, due February 7th.

**Homework 2** [.\(http://www.math.kth.se/~szepessy/HW2.pdf\)](http://www.math.kth.se/~szepessy/HW2.pdf) on Euler approximations of Ito differential equations, due February 21.

**Homework 3** [.\(http://www.math.kth.se/~szepessy/hmw3\\_2018.pdf\)](http://www.math.kth.se/~szepessy/hmw3_2018.pdf) on stochastic volatility, delta and stability, due April 7th.

**Homework 4** (<https://canvas.kth.se/courses/17788/files/2774657/download?wrap=1>)  [.\(https://canvas.kth.se/courses/17788/files/2774657/download?wrap=1\)](https://canvas.kth.se/courses/17788/files/2774657/download?wrap=1) on machine learning and Tensor Flow, due April 24th and [Python code](https://github.com/Kammo84/SF2522/blob/master/tf_lab.py) [.\(https://github.com/Kammo84/SF2522/blob/master/tf\\_lab.py\)](https://github.com/Kammo84/SF2522/blob/master/tf_lab.py).

**Homework 5** (<https://canvas.kth.se/courses/17788/files/2894054/download?wrap=1>)  [.\(https://canvas.kth.se/courses/17788/files/2894054/download?wrap=1\)](https://canvas.kth.se/courses/17788/files/2894054/download?wrap=1) on classifying figures, due May 13th, the codes are in the Canvas "Files".

In Homework 4 and 5 you need to use TensorFlow 1.x. Using TensorFlow 2.x might generate an error from the provided codes. You can use pip to install TensorFlow 1.x by following the instructions [here](https://www.tensorflow.org/install/pip). [\\_\(https://www.tensorflow.org/install/pip\)](https://www.tensorflow.org/install/pip).

SDE-poster project: Choose a paper from [the list](https://canvas.kth.se/courses/4143/files) [\\_\(https://canvas.kth.se/courses/4143/files\)](https://canvas.kth.se/courses/4143/files) before April 9th and hand in a poster-pdf-file in the link "Uppgifter", due May 9th, to be presented May 12th. Detailed information is in Section "Presentations" below.

## Presentations

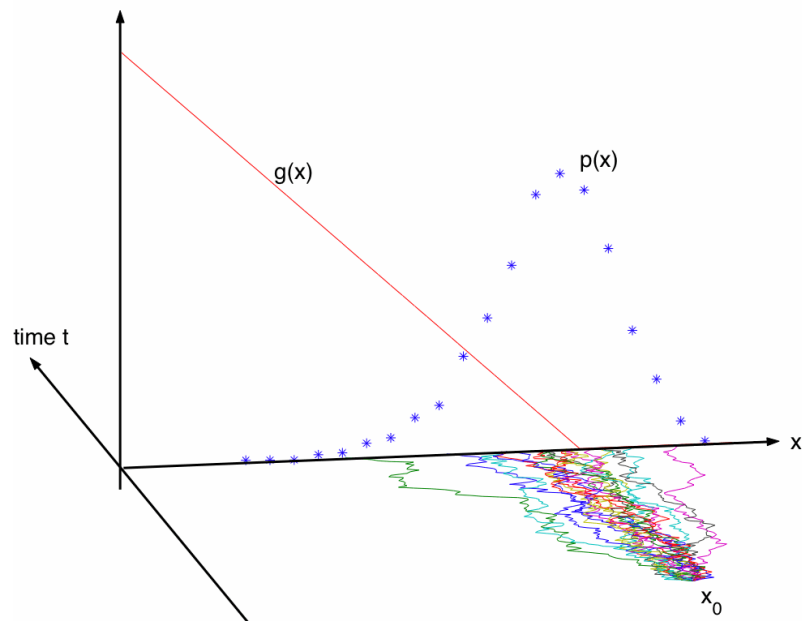
[\\_\(http://www.math.kth.se/cgi-bin/evaluation/evaluation?command=answer&evaluationid=209\)](http://www.math.kth.se/cgi-bin/evaluation/evaluation?command=answer&evaluationid=209)

[The list of Files \(https://canvas.kth.se/courses/4143/files\)](https://canvas.kth.se/courses/4143/files) includes papers to be used for the presentations. The idea is that each group of two choose a paper following the instructions in the thread "how to choose a project" in "Discussions". [Here](https://canvas.kth.se/courses/17788/pages/projects-taken) [\\_\(https://canvas.kth.se/courses/17788/pages/projects-taken\)](https://canvas.kth.se/courses/17788/pages/projects-taken) is a list of papers taken: at most two groups per paper. The groups present the results in a Zoom meeting **May 12th at 8-12** and submits a poster. Probably we have time for ten minutes for each presentation this year. You may suggest another paper. Read the literature and study the formulation and motivation of the problem. Use your knowledge and fantasy to formulate the mathematical model, the problem you want to solve and an SDE simulation. Try to use the literature to formulate interesting problems. You are welcome to discuss with the teachers.

Concerning presentations: Projects are presented by lab groups of two.

Make a poster and prepare a ten minutes presentation. Slides for the presentations can be uploaded in "Uppgifter". A good poster includes at least formulation of the problem and some results and conclusion. The posters will be posted in this Canvas page. In the KTH-library you can find online the book "Handbook of Writing for the Mathematical Sciences" by Nicholas Higham which include in chapter 12 "Preparing a Poster". If you have not made a poster before, [here](https://sv.overleaf.com/gallery/tagged/poster) [\\_\(https://sv.overleaf.com/gallery/tagged/poster\)](https://sv.overleaf.com/gallery/tagged/poster) is a link to Latex poster templates (and a [non fancy version](https://canvas.kth.se/courses/17788/files?preview=2736472)) [\\_\(https://canvas.kth.se/courses/17788/files?preview=2736472\)](https://canvas.kth.se/courses/17788/files?preview=2736472).

[Posters and schedule \(https://canvas.kth.se/courses/17788/pages/posters-and-presentation-plan\)](https://canvas.kth.se/courses/17788/pages/posters-and-presentation-plan)



Sample paths of solutions to stochastic differential equation and its probabability density