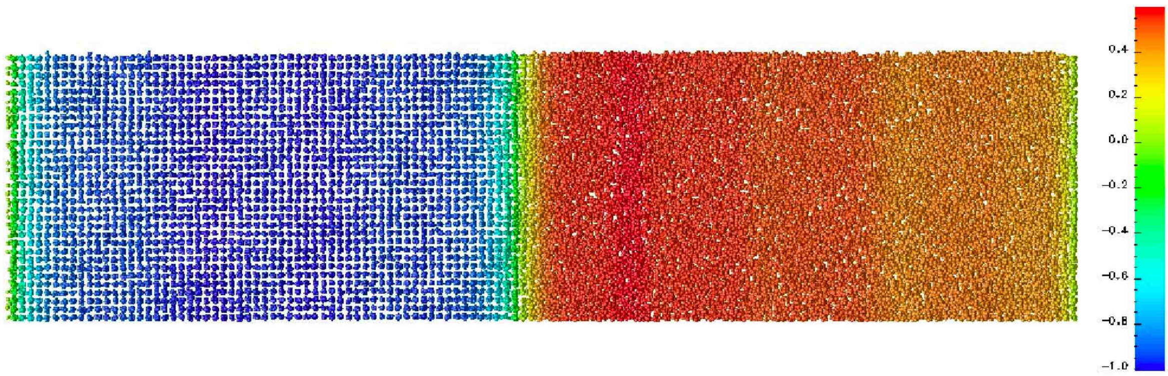
Welcome to the course Computational methods for stochastic differential equations and machine learning (joint SF2525 master level and SF3581 graduate level) 2021

OMX Stockholm 30 index för en dag, en måndag 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.

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Week     Application                        Subject

3,4,5    stocks with noise                  stochastic differential equations,
         molecular dynamics                 weak and strong convergence, Ito-calculus
         AI                                 Euler's method

6,7,8,9 option price                         The Feynman-Kac formula,
        American options                     Monte-Carlo Methods, variance reduction
                                             finite difference methods

12,13,15 optimal hedging                      calculus of variations, optimal control
         reaction rates                       dynamical programming,
                                              Hamilton-Jacobi equations,
                                              large deviations and rare events

16,17,19 machine learning                     game theory, differential games,
         AI                                   neural networks,
                                              stochastic gradient descent

20       presentations e.g:
         multi-level Monte Carlo,              variance reduction,
         ground water flow                     Convection-diffusion equations,
         neural networks, AI
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Course material and evaluation

- New version of the [lecture notes (https://canvas.kth.se/courses/22150/files?preview=2760616)](https://canvas.kth.se/courses/22150/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

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

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

Xin Huang, department of mathematics, xinhuang@kth.se, office hour .

Schedule

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Starting Friday January 22th, 13.15-15.00.
Schedule for lectures (https://cloud.timeedit.net/kth/web/public01/)

Preliminary plan, in addition guest a guest lecture, a tensor flow tutorial and a re
view
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 Feyman-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/22150/file
s?preview=2709820) and video in Media Gallery)
Lecture 10: chapter 10 Tensor flow and video Introduction to HW 4&5 (https://canvas.kt
h.se/courses/22150/files/3522430/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
Lecture 15: chapter 8.3 Hamilton-Jacobi PDE and Stochastic optimal control
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Homework, Computer Lab's , Presentations and Examination

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/22150/files?preview=2726373)**

The final grade of the course is pass/fail.

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. To pass it is required to obtain at least 3 credits on each of the homeworks 1,2,3,5 and at least 6 credits on homework 4, after possible revision.

(http://www.csc.kth.se/~szepessy/sde_teori_2008.pdf)

Homework and dates (preliminary versions)

Homework 1 (http://www.nada.kth.se//kurser/kth/2D1269/h1.pdf) on Ito integrals, due February xx.

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

Homework 3 (http://www.math.kth.se/~szepessy/hmw3_2018.pdf) on stochastic volatility, delta and stability, due April xx.

Homework 4 (https://canvas.kth.se/courses/22150/files/3522428/download?wrap=1) (https://canvas.kth.se/courses/22150/files/3522428/download?wrap=1) on machine learning and Tensor Flow, due April xx and **Python code (https://github.com/Kammo84/SF2522/blob/master/tf_lab.py)**

Homework 5 (https://canvas.kth.se/courses/22150/files/3522429/download?wrap=1) (https://canvas.kth.se/courses/22150/files/3522429/download?wrap=1) on classifying figures, due May xx, 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)**

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

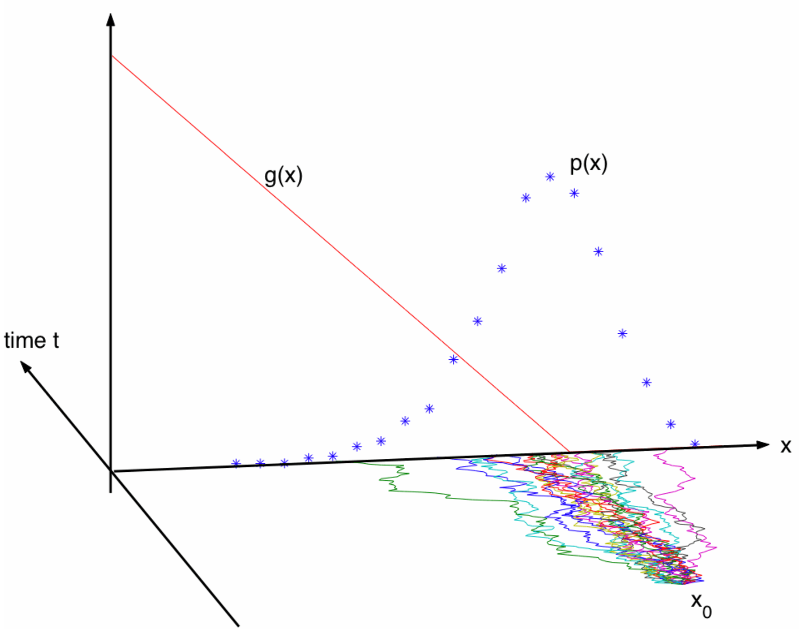
Presentations

[(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) 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** (http://xx) is a list of papers taken: at most two groups per paper. The groups present the results in a Zoom meeting **May xx** 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 modell, 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) is a link to Latex poster templates (and a **non fancy version)** (https://canvas.kth.se/courses/22150/files?preview=2736472) .

(https://canvas.kth.se/courses/22150/pages/posters-and-presentation-plan)



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