UNIVERSITY OF GOTHENBURG

# DEPARTMENT OF MATHEMATICAL SCIENCES

## NFMV020 Numerical methods and machine learning algorithms for solution of Inverse problems, 7.5 credits

Numeriska metoder och maskininlärningsalgoritmer för lösning av inversa problem , 7,5 högskolepoäng

*Third-cycle level / Forskarnivå*

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## Confirmation

This syllabus was confirmed by the Department of Mathematical Sciences on 2021-08-24, and is valid from Autumn semester 2021.

*Responsible Department*
Department of Mathematical Sciences, Faculty of Science

## Entry requirements

Numerical analysis, partial differential equations, programming in Matlab.

## Learning outcomes

Inverse and ill-posed problems arise in many real-world applications including medical microwave, optical and ultrasound imaging, MRT, MRI, oil prospecting and shape reconstruction, nondestructive testing of materials and detection of explosives, seeing through the walls and
constructing of new materials.
Physical formulations leading to ill- and well-posed problems, methods of regularization of inverse problems and numerical methods of
solution of inverse and ill-posed problems, such that Lagrangian approach and adaptive optimization, methods of analytical reconstruction and layer-stripping algorithms will be addressed. Numerical solution of ill-posed problems including methods of image reconstruction with applications in image deblurring and magnetic resonance imaging (MRI) will be presented. Machine learning classification algorithms such that regularized and non-regularized least squares and perceptron, SVM and Kernel methods
will be studied. Application of these algorithms for solution of inverse and ill-posed problems will be considered.

*Knowledge and understanding*

After a successful completion of the course the students will have knowledge and understanding on following topics:
1. Have basic understanding of the notion of inverse problems.
2. Understand main machine learning algorithms for classification (least squares and perceptron, SVM and Kernel Methods).
3. Understand basic numerical methods for solution of inverse and ill-posed problems.
4. Derive and use the numerical techniques needed for a professional solution of a given ill-posed or classification problem.

*Competence and skills*

Students will have following skills and abilities:
1. Use computer algorithms, programs and software packages to compute solutions of ill-posed or classification problem.
2. Critically analyze and give advice regarding different choices of regularization techniques, algorithms, and mathematical methods for solution of ill-posed or classification problem with respect to efficiency and reliability.
3. Critically analyze the accuracy of the obtained numerical result and present it in a visualized way.
4. Write a scientific report and make a scientific presentation summarizing obtained results.

*Judgement and approach*

A passing grade on the course will be awarded to students who:
1. Demonstrate an ability to analyze and solve an inverse or an ill-posed problem.
2. Demonstrate an ability to analyze and solve studied classification problems.
3. Demonstrate ability of using computer algorithms, programs and software packages to compute solutions of inverse, ill-posed or classification problems.

## Course content

In a first step, we will begin to give a short survey on the domain of inverse and ill-posed problems.
In the second part of the course will be considered physical formulations leading to ill- and well-posed problems, methods of regularization of inverse problems and numerical methods of solution of inverse and ill-posed problems, such that Lagrangian approach and adaptive optimization, methods of analytical reconstruction and layer-stripping algorithms, least-squares algorithms and classification algorithms. Numerical solution of ill-posed problems including methods of image reconstruction with applications in image deblurring and magnetic resonance imaging (MRI) will be presented. Machine learning classification algorithms for solution of inverse and ill-posed problems will be also studied as additional tool for improving of solutions obtained in all above described numerical methods.
This course includes the course project consisting of several assignments where some inverse or ill-posed problem should be solved
in Matlab or in C++/PETSc by algorithms studied in the course.

## Types of instruction

The material of the course includes online lectures in Zoom (slides and video lectures), description of the computer projects and open source software (Matlab codes, C++/PETSC codes). All material of the course is available in CANVAS and on the WavES project waves24.com/news.

*Language of instruction*
The course is given in English.

## Grades

The grade Pass (G) or Fail (U) is given in this course.

## Types of assessment

The examination consists of the submission of the course project together with Matlab or C++/PETSc code.

## Course evaluation

The course evaluation is carried out together with the students at the end of the course, and is followed by an individual, anonymous survey. The results and possible changes in the course will be shared with the students who participated in the evaluation and to those who are beginning the course.