Numerical Methods for Direct and Inverse Boundary Value Problems (C002206)

Course size (nominal values; actual values may depend on programme)

Credits 6.0		Study time 165 h		Contact hrs	45.0 h

Course offerings and teaching methods in academic year 2018-2019

A (semester 2)	Dutch	seminar: practical PC room classes	7.5 h
		lecture	30.0 h
		seminar: coached exercises	7.5 h

Lecturers in academic year 2018-2019

Constales, Denis	TW16	lecturer-in-charge

Offered in the following programmes in 2018-2019	crdts	offering
Master of Science in Computer Science	6	A

Teaching languages

Dutch

Keywords

Boundary value problems. ordinary and partial differential equations, inverse problems (recovery of missing data, parameter identification), numerical methods

Position of the course

This subject concerns an option course which is intrinsic for the Master in Mathematical Informatics. Subjects which constitute a direct preparation are: Analysis II, Linear Algebra and Geometry, Scientific Computing.
The purpose is to develop and analyse **reliable numerical algorithmes** for solving various **inverse boundary value problems** (BVPs). Contrary to the situation for direct BVPs, not all data in the differential equation or in the initial or boundary conditions are known. For the compensation of the **missing data**, one has very partial information on the state variable which still has to be determined. The solution methods for inverse BVPs make use of those for direct BVPs.

This fits with the following competences of the Master in Mathematical Informatics:1.2, 1.7, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.10, 3.5 en 5.3.

Contents

1 Introduction to finite element methods and finite differerence methods for direct (stationary and time dependent) boundary value problems (BVPs)
2 Recovery of missing boundary data for BVPs with superfluous nonlocal boundary conditions.
3 Discretisation of continuous inverse problems
4 Rank deficiency and ill-conditioning
5 Regularisation techniques.
6 Iterative methods.
7 Nonlinear regression. Gauss Newton and Levenbergh-Marquadt methods.
8 Practical applications to specific convection-diffusion problems (e.g. from chemical kinetics, metallurgy, hydro-geology, low frequent electromagnetism.)

Initial competences

Having followed succesfully the following courses in the Bachelor Informatics: Analysis II, Linear Algebra and Geometry, Scientific Computing.

Final competences

The ability to develop and analyse reliable numerical algorithmes to solve various types of inverse boundary value problems for linear (ordinary or partial) differential equations.

Conditions for credit contract

Access to this course unit via a credit contract is determined after successful competences assessment

Conditions for exam contract

This course unit cannot be taken via an exam contract

Teaching methods

Lecture, seminar: coached exercises, seminar: practical PC room classes

Extra information on the teaching methods

During the lectures **the theory** will be presented **in great detail at the blackboard** by the professor.
During the **work colleges** a variety of exercices will be treated, which are related to the theory and which are intended to give the students more insight in the topics and which moreover stimulate the creativity. The lecturer takes care about the **pen and paper exercices.** Furthermore, a number of **PC exercices offer** more specific interaction with FEM/FDM-methods in Fortran/C/C++ via Python or Mathlab.
Every student will also have to master **on his own** a short scientific text and to give a lecture on the indicated topic, using computer projection.
On request the learning material can be provided in English.

Learning materials and price

For the theory lessons the lecturer provides a **syllabus**, as well as copies of a few parts from the recent scientific literature.
Cost: 8 EUR

References

Aster, Richard C., e.a. *Parameter estimation and inverse problems* Burlington (M.A.) : Academic press,2005.
Colton, David, Engl, Heinz W., Louis, Alfred Karl *Surveys on solution methods for inverse problems*Wien : Springer, 2000.
Malengier, Benny *On numerical methods for direct and inverse convection-diffusion problems*(PhD-thesis), UGent, 2006
Vogel, Curtis R. *Computational methods for inverse problems* Philadelphia: SIAM, 2002.
Woodbury K. A. (ed.) *Inverse engineering handbook*Boca Raton: CRC Press, 2002.

Course content-related study coaching

The lecturer is always willing to help students who have questions on difficulties in the theory or exercices, either by **email** or in **individual explanation sessions**. There will also be interactive support through **Minerva**.

Evaluation methods

end-of-term evaluation and continuous assessment

Examination methods in case of periodic evaluation during the first examination period

Written examination with open questions, open book examination, oral examination

Examination methods in case of periodic evaluation during the second examination period

Written examination with open questions, open book examination, oral examination

Examination methods in case of permanent evaluation

Assignment

Possibilities of retake in case of permanent evaluation

examination during the second examination period is possible

Extra information on the examination methods

In the period related evaluation there is an **oral** examination of the **theory part** with a **written preparation**. The student is expected to be able to reproduce a restricted part of the topics teached, in a critical way and showing insigth. The **part exercices is written and with open book**; here creatvity and insight are crucial.
For the **lecture** during the semester, for which a short part of a scientific text must be mastered by the student on his own, he must use a **power point presentation**. The student must provide the other students and the lecturer with a **short note** on his subject one week before the presentation

Calculation of the examination mark

There is a **periodical evaluation** on the **theory and exercices**. The theory part intends to check whether the student masters sufficiently the topics treated and

whether he has gained sufficient insight. In the exercice part (with open book) the student must show tot be able to solve problems in an independent way. This exam counts for **3/4 of the total result** of this option course.

Furthermore, during the semester, each student will have to give **one lecture on a restricted part**, to be studied independently, **of a recent paper or textbook**. There will be time for questions by the other students and by the lecturer. The result obtained will count for **1/4 of the total result for this option course.**