Uniwersytet Gdański

KAPITAŁ LUDZKI
NARODOWA STRATEGIA SPÓJNOŚCI

Projekt współfinansowany przez Unię Europejską w ramach Europejskiego Funduszu Społecznego

UNIA EUROPEJSKA
EUROPEJSKI FUNDUSZ SPOŁECZNY

Course title

Numerical Methods

ECTS code

13.2.0427

Name of unit administrating study

Faculty of Mathematics, Physics and Informatics

Studies

faculty	field of study		
Faculty of Mathematics, Physics and Informatics	Quantum Information Technology	type	all
		form	all
		specialty	all
		specialization	all

Teaching staff

prof. UG, dr hab. Wiesław Miklaszewski; dr hab. Marek Krośnicki

Forms of classes, the realization and number of hours

Forms of classes

Laboratory classes, Lecture

The realization of activities

classroom instruction, online classes

Number of hours

Laboratory classes: 30 hours, Lecture: 30 hours

ECTS credits

5

The academic cycle

2022/2023 winter semester

Type of course

obligatory

Language of instruction

english

Teaching methods

- critical incident (case) analysis
- multimedia-based lecture
- problem solving
- project-based method (research, implementation, practical project)

Form and method of assessment and basic criteria for eveluation or examination requirements

Final evaluation

- Graded credit
- Examination

Assessment methods

- (mid-term / end-term) test
- written exam with open questions
- written exam (test)

The basic criteria for evaluation

5 questions/problems to be solved from the list of 20 problems discussed/explained during the lecture. The list is published in advance. Correct answer to at least 3 of 5 questions

computer project report (2 projects)

Method of verifying required learning outcomes

established effect of education	exam	projects
W01	+	+
W02	+	+
W03	+	+
W04	+	-
W05	+	+
U01	-	+
U02	-	+
U03	-	+
K01	+	-

Required courses and introductory requirements

A. Formal requirements

NONE

B. Prerequisites

Basic knowledge of numerical methods at first degree level

Aims of education

This course is an advanced course of numerical methods for quantum information . To explore quantum information one require computational methods since mathematical models are only rarely solvable algebraically. Numerical methods, based upon computational mathematics and quantum physics, are the basic algorithms enabling computer predictions in quantum information. Such methods include techniques for optimization, linear algebra underlying eigenvalue problem, stochastic simulation

Course contents

Optimization: basic concepts, computational complexity.
Linear programming: simplex method, duality and sensitivity.
Unconstrained optimization: method of steepest descent, Newton's method, conjugate gradient algorithm; linear least squares, robust optimization.
Constrained optimization: projected gradient methods; sequential unconstrained minimization, convex optimization, nonlinear optimization.
Combinatorial optimization: simulated annealing.
Maximum likelihood estimation.
Evolutionary algorithm.
Singular value decomposition, the pseudo-inverse.
Matrix eigenvalues: Jacobi's method, Givens' transformation, Householder transformation, the LR method, the QR method.
Maximum (minimum) modulus eigenvalue: power method, inverse power iteration, shifted inverse power iteration.
The general eigenvalue problem.
Numerical methods for sampling from a given density
Numerical simulations of master equations.
Software for optimization, eigenproblem solution and stochastic simulations.

Bibliography of literature

G. S. Chirikjian, Stochastic Models, Information Theory, Analytic Methods and Modern Applications and Lie Groups,Vol. 2, Analytic Methods and Modern Applications, Springer Science+Business Media, 2012
S. Butenko, P.M. Pardalos, Numerical Methods and Optimization, An Introduction, Taylor & Francis Group 1014
S. K. Bose, Numerical Methods of Mathematics Implemented in Fortran, Springer Nature Singapore Pte Ltd. 2019
A. Kharab, R. B. Guenther, An Introduction to Numerical Methods, A MATLAB Approach, Taylor & Francis Group, 2019
É. Walter, Numerical Methods and Optimization, A Consumer Guide, Springer International Publishing Switzerland 2014
G. Lindfield, J. Penny, Numerical Methods Using MATLAB, Elsevier 2019
R. Toral, P. Colet, Stochastic Numerical Methods, An Introduction for Students and Scientists, Wiley-VCH 2014
R. K. Gupta, Numerical Methods Fundamentals and Applications, Cambridge University Press 2019
B. Extracurricular readings

The learning outcomes (for the field of study and specialization)

K_W01
Student has extensive knowledge of general physics and advanced knowledge in the area of quantum information

Knowledge

W01
has advanced knowledge about optimization numerical methods (K_W02)
W02
knows numerical methods for solution of the eigenvalue problem (K_W02, K_W06)

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theory; knows the history of the development of quantum information theory and its importance for the progress of science, world cognition and social development

K_W02
Student has in-depth knowledge of advanced mathematics, mathematical and computer methods necessary to solve physical problems of medium complexity and advanced in the area of quantum information and its technological aspects

K_W03
Student knows advanced experimental, observational and numerical techniques allowing to plan and perform a complex physical experiment or computer simulation

K_W05
Student knows the theoretical basis of computational methods and information techniques used to model and simulate physical systems considered in the theory of quantum information

K_W06
Student has knowledge of the current trends in the development of physics, in particular within the quantum information theory

K_U01
Student can apply mathematical knowledge to formulating, analyzing and solving problems related to information theory

K_U02
Student can apply mathematical knowledge and mathematical tools to formulate and solve problems within the framework of quantum information theory

K_U03
can make a critical analysis of observations or theoretical calculations along with the assessment of the accuracy of the results

K_U05
has the ability to synthesize methods and ideas from various areas of physics and other exact and natural sciences; is able to notice that often distant phenomena are described by similar models

K_U07
can present the results of research (experimental, theoretical or numerical) in writing, orally, as a multimedia presentation or as a poster

K_K02
Student is aware of the decisive role of experiment in verifying physical theories; he is aware of the existence of a scientific method in collecting knowledge
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W03
Student understands stochastic simulation methods (K_W01, K_W02, K_W05)
W04
Student knows the proofs of the main facts (K_W02)
W05
Student knows numerical algorithms used to model selected physical phenomena (K_W01, K_W02, K_W03, K_W05, KW06))
Skills
U01
is able to solve numerically an optimization problem or an eigenvalue problem and analyze obtained results (K_U02, K_U03, K_U05)
U02
is able to use theoretical knowledge in the numerical analysis to prepare and run an efficient computer code (K_U01, K_U03)
U03
is able to write a report about solved numerically project (K_U07)
Social competence
K01
The student knows the meaning of the numerical experiment in physical sciences (K_K01)
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