Course guide
270031 - CN - Numerical Computation

Last modified: 30/01/2024

Unit in charge: Barcelona School of Informatics
Teaching unit: 749 - MAT - Department of Mathematics.

Degree: BACHELOR'S DEGREE IN INFORMATICS ENGINEERING (Syllabus 2010). (Optional subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** Catalan

LECTURER

Coordinating lecturer: IRENE MARÍA DE PARADA MUÑOZ

Others: Segon quadrimestre:
IRENE MARÍA DE PARADA MUÑOZ - 11, 12

REQUIREMENTS

- Prerequisite M1
- Prerequisite M2

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CCO1.1. To evaluate the computational complexity of a problem, know the algorithmic strategies which can solve it and recommend, develop and implement the solution which guarantees the best performance according to the established requirements.
CCO2.3. To develop and evaluate interactive systems and systems that show complex information, and its application to solve person-computer interaction problems.
CCO2.6. To design and implement graphic, virtual reality, augmented reality and video-games applications.

Generical:
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

TEACHING METHODOLOGY

Classes of Theory: The theory classes will consist of presenting a real problem and the definition and construction of concepts, methods and techniques necessary to resolve the situation and to do, in addition, a prediction for problems or situations presented to the next. To solving problems that complement and / or extend the theoretical and presented examples of the theory classes.

Practical Classes: Classes will consist of laboratory studies and visualization algorithms worked on the theory class, using a numerical software -Matlab, Octave- more input from symbolic manipulator -Maple- . These exercises will be introduced initially by the teacher in a classroom PCs and the students continue to interactively according to a previously prepared script of the session.

Practices: Each student will perform more than five short practices in Matlab corresponding to the first five chapters. These practices consist of one or more application routines proposed by the teacher to solve a particular practical problem numerically.

LEARNING OBJECTIVES OF THE SUBJECT

1.Analysis, programming, interpretation and verification of results, documentation and prediction of the mathematical model to study. Knowledge of the capacity of the machine where epsilon is working. Calculus of functions and numerical error propagation and representation of data. Ability to study the problem and its numerical stability: ill conditioned problems. Calculation of effective capacity and series acceleration of convergence.
2.Distinguish between methods of interpolation and approximation of functions. Master the interpolation methods: linear system, Lagrange, Newton and Txebixev. Learn the advantages and disadvantages of each. Differentiate between Lagrange polynomial interpolation and hermitiana, and know to use them as appropriate. Choose the method of approximation: error in the choice of nodes, minimum squared error and the standard error of sub-infinite interval.
3.Evaluation of the technical resolution to use depending on the size of the system: direct or iterative. Estimate condition number of the matrix system. Calculation of cash values ☐☐and their application in various models.
4.Get dominate the methods of numerical integration of differential equations and simpler problems involving the integration step reduction or improvement of computation time with a step too large.
5.Analyze and decide the most efficient method to compute solutions of a nonlinear equation. Studying the concept of order and the computational cost for iterative methods. Learn some tolerance requiring the calculation, counting the number of iterations necessary to introduce a set of initial approximations, the problem applied to several examples with varying difficulty.
6.Discretize the equations, analyze the failure of local and global problem solving associated systems of equations.
7.Consider the possibilities that may present a problem, achieving a versatility that makes possible wider application in terms of the diversity question.

STUDY LOAD

Type	Hours	Percentage
Hours large group	30,0	20.00
Self study	84,0	56.00
Guided activities	6,0	4.00
Hours small group	30,0	20.00

Total learning time: 150 h

CONTENTS

PRELIMINARIES

Description:
Introduction to the course; Methodology; Programme; Bibliography; Evaluation.
What is CN? Mathematical modelling. Sources of error, and the stability of algorithms.
Floating point arithmetical representation. Error analysis.
Calculating series. Accelerating convergence.

POLYNOMIAL INTERPOLATION

Description:
Polynomial interpolation: Lagrange Method. Newton divided difference method.
Interpolation errors. Choice of nodes. Tchebichev polynomials.
Runge"s phenomenon. Hermite interpolation.

NUMERICAL LINEAR ALGEBRA

Description:
System of Linear Equations. Directe methods: Gaussian elimination. LU decomposition. Iterative methods.
Eigenvalues and Eigenvectors. The power method. The QR method. Singular values.

ZEROS OF NONLINEAR FUNCTIONS

Description:
Nested interval methods and iterative methods.
Convergence order and method efficiency.
Accelerating convergence.

NUMERICAL INTEGRATION

Description:
Numerical derivation. Truncation error. Richardson extrapolation
Numerical integration: Newton-Côtes formulae. Romberg"s Method.
Adaptive integration. Improper integrals.
Gaussian integration.

INTRODUCTION TO ORDINARY DIFFERENTIAL EQUATIONS

Description:
Initial value problems: Introductory examples. Pass methods. Multi-pass methods.
Differential equations. Consistency, stability, and convergence. Stiff equations.
Boundary value problems. The Finite Difference Method applied to linear problems.

INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS

Description:
Introductory examples: heat and wave equations. Finite Difference Method and the Finite Elements Method.
Consistency, stability and convergence. Numerical resolution.

ACTIVITIES

Introduction to Matlab

Specific objectives:
1

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 4h
Laboratory classes: 2h
Self study: 2h

Preliminaries.

Specific objectives:
1

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 10h
Theory classes: 4h
Laboratory classes: 2h
Self study: 4h

Polynomial interpolation.

Specific objectives:
2

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 10h
Theory classes: 2h
Laboratory classes: 2h
Self study: 6h

Numerical linear algebra.

Specific objectives:
3

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 27h
Theory classes: 8h
Laboratory classes: 8h
Self study: 11h

Zeros of nonlinear functions.

Specific objectives:
5

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 12h
Theory classes: 4h
Laboratory classes: 4h
Self study: 4h

Practical delivery 1

Specific objectives:
1, 2, 3, 5

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 14h
Self study: 14h

First test using MATLAB®

Description:
The set of problems to be solved deal with the following contents:
- PRELIMINARIES
- POLYNOMIAL INTERPOLATION
- NUMERICAL LINEAR ALGEBRA.
- ZEROS OF NONLINEAR FUNCTIONS

Specific objectives:
1, 3, 5, 7

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 6h
Guided activities: 2h
Self study: 4h

Numerical integration.

Specific objectives:
4

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 14h
Theory classes: 4h
Laboratory classes: 4h
Self study: 6h

Practical delivery 2

Specific objectives:
1, 4, 5, 7

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 14h
Self study: 14h

Differential Equations.

Specific objectives:
6, 7

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 13h
Theory classes: 4h
Laboratory classes: 4h
Self study: 5h

Second test.

Description:
The set of problems to be solved deal with the following contents:
- ZEROS OF NONLINEAR FUNCTIONS
- NUMERICAL INTEGRATION
- INTRODUCTION TO ORDINARY DIFFERENTIAL EQUATIONS

Specific objectives:
1, 2, 4, 5, 6, 7

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 6h
Guided activities: 2h
Self study: 4h

Third partial test. Basic theoretical concepts and exercises

Description:
Content associated with this activity:
- PRELIMINARIES
- POLYNOMIAL INTERPOLATION
- NUMERICAL LINEAR ALGEBRA.
- ZEROS OF NONLINEAR FUNCTIONS
- NUMERICAL INTEGRATION
- INTRODUCTION TO ORDINARY DIFFERENTIAL EQUATIONS

Specific objectives:
1, 2, 3, 5, 7

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 5h
Guided activities: 1h
Self study: 4h

Final assessment exam: Basic theoretical concepts and exercises, problems and practices with Matlab.

Description:
Content associated with this activity:
- PRELIMINARIES
- ZEROS OF NONLINEAR FUNCTIONS
- NUMERICAL LINEAR ALGEBRA
- NUMERICAL INTERPOLATION
- NUMERICAL INTEGRATION
- INTRODUCTION TO ORDINARY DIFFERENTIAL EQUATIONS
- INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS.

Specific objectives:
1, 2, 3, 4, 5, 6, 7

Related competencies :
G9. PROPER THINKING HABITS: capacity of critical, logical and mathematical reasoning. Capacity to solve problems in her study area. Abstraction capacity: capacity to create and use models that reflect real situations. Capacity to design and perform simple experiments and analyse and interpret its results. Analysis, synthesis and evaluation capacity.

Full-or-part-time: 15h
Guided activities: 3h
Self study: 12h

GRADING SYSTEM

Continuous assessment.

It is the recommended option for students who attend class regularly. In the evaluation of the course will participate together several concepts that will lead to the final grade:

NOTA_CURS = 0,3*PRAC+0,3*TEO+0,4*PROBS

1.- Grade PRAC. Reports of MATLAB® practices (3 points).
2.- Grade TEO. Test for the most basic concepts of theory and practice (3 points). It consists of a short answer test questions.
3.- Grade PROBS. Two or more tests of problems with Matlab (4 points).

Single assessment.

It is the option recommended for the students that does NOT attend class regularly.
The single assessment. consists of a single exam with theory, problems and practice, which evaluates the knowledge of the whole subject. In the practice part and problems part, the student is asked to use the MATLAB software. The date is set by the Faculty in the calendar of final exams.

The technical skills are worth 60% of the course. The cross-competition is worth 40%. The note will be calculated cross competition from activities in the classroom and laboratory practices delivered.

BIBLIOGRAPHY

Basic:
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- Grau, M.; Noguera, M. Cálculo numérico. Barcelona: Edicions UPC, 2001. ISBN 8483014556.
- Faires, J.D.; Burden, R.L. Métodos numéricos. 3a ed. International Thomson Paraninfo, 2004. ISBN 8497322800.
- Quarteroni, Alfio; Saleri, Fausto. Cálculo Cientifico con MATLAB® y Octave. Milan: Springer, 2006. ISBN 978884700503.
- Aubanell, A.; Benseny, A.; Delshams, A. Eines bàsiques de càlcul numèric: amb 87 problemes resolts. Universitat Autònoma de Barcelona, 1991. ISBN 8479292318.

Complementary:
- Press, W.H. [et al.]. Numerical recipes: the art of scientific computing. 3rd ed. Cambridge University Press, 2007. ISBN 9780521884075.
- Dahlquist, G.; Björck, A. Numerical methods. Dover, 2003. ISBN 0486428079.
- Wilkinson, J.H. The algebraic eigenvalue problem. Clarendon, 1965. ISBN 0198534183.
- Moler, Cleve B. Numerical Computing with MATLAB. Philadelphia: SIAM, 2004. ISBN 9780898715606.

RESOURCES

Hyperlink:
- https://es.mathworks.com/matlabcentral/fileexchange/- https://es.mathworks.com/moler.html- https://nm.mathforcollege.com/