270031 - CN - Numerical Computation

Coordinating unit: 270 - FIB - Barcelona School of Informatics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2017
Degree: BACHELOR'S DEGREE IN INFORMATICS ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 6
Teaching languages: Catalan

Teaching staff

Coordinator: Maria Àngela Grau Gotés (angela.grau@upc.edu)

Requirements

- Prerequisite M2
- Prerequisite M1

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.

Generic:
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.

Problem Classes: These classes will be devoted mainly to solving problems that complement and/or extend the theoretical and presented examples of the theory classes.

Lab classes: Classes will consist of laboratory studies and visualization algorithms worked on the theory class, using a numerical software Matlab, Octave, Freema... more input from symbolic manipulator Maple, Maxima... . 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 five short practices in C++ 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**

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Theory classes: 30h</th>
<th>20.00%</th>
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<tbody>
<tr>
<td>Practical classes:</td>
<td>15h</td>
<td>10.00%</td>
</tr>
<tr>
<td>Laboratory classes:</td>
<td>15h</td>
<td>10.00%</td>
</tr>
<tr>
<td>Guided activities:</td>
<td>6h</td>
<td>4.00%</td>
</tr>
<tr>
<td>Self study:</td>
<td>84h</td>
<td>56.00%</td>
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</tbody>
</table>
Content

PRELIMINARIES

Degree competences to which the content contributes:

Description:

POLYNOMIAL INTERPOLATION

Degree competences to which the content contributes:

Description:

LINEAR SYSTEMS AND EIGEN VALUES

Degree competences to which the content contributes:

Description:
Direct methods: Gaussian (Gauss-Jordan) elimination and LU factorisation.

Compact methods. Inverse calculations.

Introduction to matricial norms. Error constraints
Concept of eigenvalues and eigenvector. Associated real problems.
Powers and derivatives method.
Householder QR factorisation.
Eigenvalues for symmetric tridiagonal matrices. QR method.

NUMERICAL INTEGRATION

Degree competences to which the content contributes:

Description:
Richardson's Extrapolation.
Adaptive integration. Improper integrals.
Gaussian integration.
### Zeros of Non-linear Functions

**Degree competences to which the content contributes:**

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

**Description:**

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

### Introduction to Ordinary Differential Equations

**Degree competences to which the content contributes:**

**Description:**

- Boundary value problems. The Finite Difference Method applied to linear problems.

### Introduction to Partial Differential Equations

**Degree competences to which the content contributes:**

**Description:**

### Planning of activities

#### Second theory test.

**Description:**
Content associated with this activity:
- numerical integration
- SOLVING NONLINEAR EQUATIONS
- INTRODUCTION TO ordinary differential equations
- INTRODUCTION TO Partial Differential Equations

**Specific objectives:**
4, 5, 6, 7

**Hours:** 7h 30m  
Guided activities: 1h  
Self study: 6h 30m

#### Final exam.

**Description:**
Content associated with this activity: PRELIMINARY polynomial interpolation LINEAR SYSTEMS AND EQUITY SECURITIES numerical integration Zero NONLINEAR FUNCTIONS INTRODUCTION TO INTRODUCTION TO ordinary differential equations Partial Differential Equations

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

**Hours:** 15h  
Guided activities: 3h  
Self study: 12h

#### First partial test theory.

**Description:**
Content associated with this activity:
- PRELIMINARY, POLYNOMIAL INTERPOLATION, and LINEAR SYSTEMS AND EIGENVALUES.

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

**Hours:** 7h  
Guided activities: 1h  
Self study: 6h

#### Introduction to Matlab

**Hours:** 3h  
Theory classes: 0h  
Practical classes: 0h  
Laboratory classes: 2h  
Guided activities: 0h  
Self study: 1h

**Specific objectives:**
1
# Preliminaries

**Hours:** 14h 30m  
Theory classes: 4h  
Practical classes: 3h  
Laboratory classes: 0h  
Guided activities: 0h 30m  
Self study: 7h

**Specific objectives:**  
1

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# Polynomial interpolation.

**Hours:** 17h 30m  
Theory classes: 4h  
Practical classes: 2h  
Laboratory classes: 2h  
Guided activities: 0h 30m  
Self study: 9h

**Specific objectives:**  
2

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# Numerical linear algebra.

**Hours:** 28h 30m  
Theory classes: 8h  
Practical classes: 4h  
Laboratory classes: 3h  
Guided activities: 0h 30m  
Self study: 13h

**Specific objectives:**  
3

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# Numerical integration.

**Hours:** 17h 30m  
Theory classes: 4h  
Practical classes: 2h  
Laboratory classes: 2h  
Guided activities: 0h 30m  
Self study: 9h

**Specific objectives:**  
4
| **Zeros of functions.** | **Hours:** 17h 30m  
Theory classes: 4h  
Practical classes: 2h  
Laboratory classes: 2h  
Guided activities: 0h 30m  
Self study: 9h |
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<tbody>
<tr>
<td><strong>Specific objectives:</strong></td>
<td>5</td>
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</table>

| **Differential Equations.** | **Hours:** 17h 30m  
Theory classes: 4h  
Practical classes: 2h  
Laboratory classes: 2h  
Guided activities: 0h 30m  
Self study: 9h |
<table>
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<td><strong>Specific objectives:</strong></td>
<td>6, 7</td>
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| **First Matlab test.** | **Hours:** 2h 30m  
Guided activities: 1h  
Self study: 1h 30m |
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<tr>
<td><strong>Description:</strong></td>
<td>The set of problems to be solved deal with the following contents: PRELIMINARY, POLYNOMIAL INTERPOLATION, and LINEAR SYSTEMS AND EIGENVALUES.</td>
</tr>
<tr>
<td><strong>Specific objectives:</strong></td>
<td>1, 2, 3, 7</td>
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</tbody>
</table>

| **Second Matlab test.** | **Hours:** 2h  
Guided activities: 1h  
Self study: 1h |
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>The set of problems to be solved deal with the following contents: MATLAB, SOLVING NONLINEAR EQUATIONS, INTRODUCTION TO ordinary differential equations, INTRODUCTION TO Partial Differential Equations.</td>
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<td><strong>Specific objectives:</strong></td>
<td>1, 4, 5, 6, 7</td>
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</tbody>
</table>
Qualification system

In the evaluation of the course will participate together several concepts that will lead to the final grade:

FINAL_GRADE = LABO+PRAC+TEO+PROBS

1.- Grade LABO. The classes of laboratory-practice exercises in Matlab or Octave (2 points). Two or more tests.
2.- Grade PRAC. Two reports of Matlab or Octave practices (2 points).
3.- Grade TEO. Two or more test for the most basic concepts of theory (2 points). It consists of a short answer test questions.
4.- Grade PROBS. The final test of problems with Matlab and books (4 points) will be held in class time (duration: two hours).

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.

NOTA_CURS = LABO+PRAC+TEO+PROBS

Bibliography

Basic:
Grau, M.; Noguera, M. Càlcul numèric: teoria i pràctica [on line]. Edicions UPC, 2000Available on:


Complementary:


Others resources:

Hyperlink


https://es.mathworks.com/matlabcentral/fileexchange/

https://es.mathworks.com/moler.html