Numerical and Probabilistic Methods

Code: 104395
ECTS Credits: 6

2025/2026

Degree	Type	Year
Computational Mathematics and Data Analytics	OB	2

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Teachers

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Teaching groups languages

You can view this information at the end of this document.

Prerequisites

It is advisable to have done at least one course of analysis, linear algebra and probability.

Objectives and Contextualisation

In the analysis courses, we were taught to compute areas of functions by means of integrals, but also that not all functions have an integral that can be expressed in a finite amount of elementary functions.
In the algebra courses we were taught that a polynomial of degree n has n roots (real or complex), but also that not all the degree 5 or higher polynomials have necessarily to be solved by means of radicals. And also that many other non-polynomic equations cannot be explicitly resolved.
In the algebra courses we have been taught to solve systems of linear equations using the Cramer method, but do you know that solving a 20x20 system in this way would need more time than the universe has?
In the first course of numerical calculus, some methods were introduced to solve this type of problems, not by exact way, but by numerical approximations. This way of tackling problems presents some advantages and some drawbacks. The main advantages are that in this way you can solve problems that would otherwise be impossible to solve. One drawback is that the exact solution is never found but a numerical approximation. This is compensated by the advantage that we can decide a priori the degree of precision with which we want to obtain the solution and this can be as great as we wish (and we have a computer good enough to do so in a reasonable time). Another disadvantage is that the numerical calculation is permanently fighting against all kinds of errors in the initial data, in the introduction data, and in rounding up operations. These bugs also propagate as we do more and more operations with data already corrupt. Therefore, numerical calculation methods should also be able to deal with this problem.
The first course of numerical calculus ended with the resolution of integrals in numerical form. In this second year we will continue doing with new more powerful methods.

Another way of calculating integrals, for more unlikely it may seem, is by means of random methods. These methods have traditionally been called Montecarlo methods as a paradigm of the Mecca of gambling. We will see how with very simple (although long calculation) methods it is possible to calculate function areas in one or more dimensions, which would otherwise be impossible to calculate.
In this course we will present a new type of mathematical problems that are very common in the modelling of problems of real life, in fact, few real life problems end up simply needing the calculation of an integral or solution of a polyomial equation. Most of the problems that arise in real life end up in problems of differential equations, whether ordinary or partial. In a problem of differential equations, the goal is not to find a number to solve a problem, but to find a function.
Some problems of ordinary differential equations can be solved in exactly way and this has been done in more detail in the first semester subject which is called ordinary differential equations. However, since many differential equations are not solvable in either algebraic or analytic with a finite number of terms, it is also necessary to use numerical tools to solve them.

Learning Outcomes

1. CM12 (Competence) Compare the use of numerical calculus with the use of abstraction in mathematics to solve a problem.
2. CM13 (Competence) Control the errors produced by machines when calculating.
3. SM12 (Skill) Develop independent strategies to solve numerical method problems, differentiating between routine and non-routine problems and designing a strategy to solve a problem.
4. SM13 (Skill) Use algorithmic and data representation structures suitable for solving a mathematical problem.

Content

1.- Numerical integration. Newton-Côtes and Gaussian methods
2.- Monte Carlo methods for calculating areas
2.1- Generation of random variables
3.- Numerical integration of ordinary differential equations (one variable)
3.1- Initial value problem
3.1.1- Euler method
3.1.2- Order of consistency and convergency
3.1.3- Taylor methods
3.1.4- Runge-Kutta methods
3.1.5- Variable Step methods
3.1.6- Multistep methods
3.2- Problem of values at the border
3.2.1- Shooting method
3.2.2- Split Differences method

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Lab exercices	14	0.56	
Problem classes	8	0.32	

Theoretical classes	27	1.08
Type: Autonomous		
Study, exercises and preparation of lab exercises	96	3.84

The tools of mathematics, and very particularly those of numerical calculus need to be learned and practiced. Simply memorizing a formula or a theorem, if we have not applied it at any time, it is possible that it does not go to the first tries. In addition, the numerical calculation tools have been done to solve problems that need a lot of calculations and these calculations will normally be done by a computer, with a program that we have done. Even if the program is made by another person, it is convenient to know how it works in order to detect if any result can be unstable or incorrect.

But we can not make a program to apply a method if we previously have not practiced it, even if it is with a simple or even trivial problem that would not even have a need of the numerical method.

The theoretical sessions will be dedicated to the teacher's presentation of the different methods and their analysis. The exhibition of the methods will be accompanied by examples of their behavior, carried out with computers, which are aimed at both facilitating the understanding of the method and motivating their analysis.

Problems of theoretical and calculation types are resolved in the problem sessions. In the case of calculation problems, there will be some requiring the use of a calculator or even the use of a computer. In the latter case, the problems will not be computationally intensive, so the necessary algorithms may be implemented quickly in a numeric language interpreter or even in a spreadsheet (Excl). The teacher will combine the resolution of problems for the whole class, on the part of a student throughout the class and for all students at the same time, in a group, with the teacher's help.

The computer practice sessions form part of the subject dedicated to introducing scientific computing. They will be dedicated to the solution of computationally more intensive problems, which will be implemented in a compiled language. In solving these problems students will progressively construct their personal library of routines that implement basic numerical methods.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continous Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Computer Program	0.4	0	0	SM12, SM13
Final exam	0.39	3	0.12	CM12, CM13
Partial exam	0.21	2	0.08	CM12, CM13

The course evaluation will take place from three activities:

1. Partial Exam (EP): Exam of part of the course, with theoretical questions and problems.
2. Final Exam (EF): Exam of the whole subject, with theoretical questions and problems.

3. Computer Labs (PR): Delivery of code and a report.

In addition, students will be able to take a retake exam (ER) with the same characteristics as the EF exam. If the student takes the retake exam the grade of ER will replace the grades EP and EF (that is, the grades EP and EF will be equal to the grade obtained in the retake exam). The practices will not be recoverable.
It is a prerequisite to overcome the course that Max (0.35 * EP + 0.65 * EF, EF) > = 3.5 and PR > = 3.5.
The final grade of the course will be 0.6 * MAX (0.35 * EP + 0.65 * EF, EF) + 0.4 * PR
The honour qualifications will be awarded to the first complete evaluation of the course. They will not be withdrawn if another student obtains a higher qualification after considering the ER exam.
A student who has not done any written examination will be qualified as "Not evaluated"

Unique assessment

Students who have opted for the single assessment modality must take the final exam (EF) of the subject on the same date as students in the continuous assessment. This test will account for 60% of the grade. On this same date, the student must submit the project and internship report and, if the teacher requires it, an oral assessment of the internship will be carried out. The evaluation of the internship will account for 40% of the final grade. In addition, students will be able to take a retake exam (ER) with the same characteristics as the EF exam. If the student takes the retake exam the grade of ER will replace the grade EF (that is, the grade EF will be equal to the grade obtained in the retake exam). It is a prerequisite to overcome the course that EF > = 3.5 and PR > = 3.5.

Bibliography

Basic bibliography:
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J.D. Faires, R. Burden. Métodos numéricos, 3a ed. Thomson, 2004.
G. Dahlquist, A. Björk. Numerical methods. Prentice Hall, 1964.
R. Burden, J.D. Faires. Numerical analysis, 6a ed. Brooks/Cole, 1997. En castellà: Análisis numérico, 6a ed., International Thomosn, 1998.
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E. Isaacson, H.B. Keller. Analysis of numerical methods. Wiley, 1966.
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A. Ralston and P. Rabinowitz. A first course in numerical analysis. McGraw-Hill, 1988.
A. Quarteroni, R. Sacco and F. Saleri. Numerical Mathematics. Springer, 2000.

Software

The student could choose to do the programs in Python, R or C.

Groups and Languages

Please note that this information is provisional until 30 November 2025. You can check it through this link. To consult the language you will need to enter the CODE of the subject.

Name	Group	Language	Semester	Turn
(PLAB) Practical laboratories	1	Catalan	second semester	morning-mixed

(SEM) Seminars	1	Catalan	second semester	morning-mixed
(TE) Theory	1	Catalan	second semester	morning-mixed