Numerical methods in biomedicine

Academic Year: (2018 / 2019) **Review date: 25-01-2019**

Department assigned to the subject: Mathematics Department

Coordinating teacher: SECO FORSNACKE, DANIEL

Type: Basic Core ECTS Credits : 6.0

Year : 2 Semester : 2

Branch of knowledge: Engineering and Architecture

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Calculus I, Calculus II, Linear Algebra, Differential Equations, Computer Programming.

OBJECTIVES

Using NUMERICAL METHODS -NM- to calculate approximate solutions of models of physiological, cellular, and molecular systems.

Study the stability and accuracy of NM.

Calculate numerical solution of systems of nonlinear equations.

Approximate the minimum of a function of several variables.

Developing, analyzing, and implementing finite difference methods.

Solving ordinary differential equations and systems by numerical integration methods.

Using the software environments to discuss the efficiency, pros and cons of different NM.

DESCRIPTION OF CONTENTS: PROGRAMME

PROGRAMME

1- PRINCIPLES OF NUMERICAL MATHEMATICS.
Well-Posedness and Condition Number of a Problem.
Stability of Numerical Methods.
The Floating-Point Number System.

2- ROOTFINDING OF NONLINEAR EQUATIONS.
Conditioning of a Nonlinear Equation.
The Newton-Raphson Method.
Newton's Methods for Simultaneous Nonlinear Equations.

3- UNCONSTRAINED OPTIMIZATION.
Necessary and Sufficient conditions for Optimality. Convexity.
Optimization Methods.

4- FINITE DIFFERENCE METHODS: INTERPOLATION, DIFFERENTIATION AND INTEGRATION.
Backward, Forward, and Central Differences.
Interpolation and Extrapolation methods.

5- NUMERICAL SOLUTIONS OF ORDINARY DIFFERENTIAL EQUATIONS (ODEs).
ODEs and Lipschitz Condition.
One Step Numerical Methods.
Zero-Stability, Convergence Analysis and Absolute Stability.
Consistency.
Numerical methods for ODEs.
Systems of ODEs.
Stiff Problems.

6- APROXIMATION THEORY.
Fourier Transform.

LEARNING ACTIVITIES AND METHODOLOGY

One of the purposes of this course is to provide the mathematical foundations of numerical methods, to analyze their basic theoretical properties (stability, accuracy, computational complexity), and demonstrate their performances on examples and counterexamples which outline their pros and cons. The primary aim is to develop algorithmic thinking-emphasizing on long-living computational concepts. Every chapter is supplied with examples, exercises and applications of the discussed theory. The course relies throughout on well tested numerical procedures for which we include codes and test files.

Students should write their own codes by studying and eventually rewriting the codes given by the Teacher in Aula Global. The personal codes should be run, tested and given up in Aula Global in the Computer Room classes.

Throughout the course we emphasize graphic 2D and 3D representations of solutions. Through this visual approach, students will have a chance to experience the meaning, i.e. to understand what a solution means and how it behaves.

ASSESSMENT SYSTEM

The final grade will come from: 60% final exam + 40% midterm short exams, computational exercises, numerical problems and applications that will be sent by Aula Global in the computer room sessions.

% end-of-term-examination:	60
% of continuous assessment (assigments, laboratory, practicals…):	40

BASIC BIBLIOGRAPHY

- [A] K. Atkinson Elementary Numerical Analysis, John Wiley & Sons, 2004
- [BC] A. Belegundu and T. Chandrupatla Optimization Concepts and Applications in Engineering, Cambridge University Press, Second Edition. 2011., 2011
- [BF] R. L. Burden, J. D. Faires Numerical Methods, Brooks/Cole, Cengage Learning,, 2003
- [DCM] S. Dunn, A. Constantinides and P. Moghe Numerical Methods in Biomedical Engineering, Elsevier Academic Press, 2010
- [DH] Peter Deuflhard and Andreas Hohmann Numerical Analysis in Modern Scientific Computing. An Introduction. Second Edition., Springer, 2003
- [FJNT] P.E. Frandsen, K. Jonasson, H.B. Nielsen, O. Tingleff Unconstrained Optimization, IMM, DTU, 1999
- [QSG] A. Quarteroni, F. Saleri and P. Gervasio Scientific computing with MATLAB and Octave, Springer, 2010
- [QSS] A. Quarteroni, R. Sacco and F. Saleri Numerical Mathematics, Springer, 2007
- [T] Lloyd N. Trefethen Finite Difference and Spectral Methods for Ordinary and Partial Differential Equations, freely available online, 1996

ADDITIONAL BIBLIOGRAPHY

- [HH] D. Higham and N. Higham Matlab Guide, Second Edition. , 2005.
- [K] C. Kelley Iterative Methods for Optimization, SIAM, 1999.