M387D - CSE 383L Numerical Analysis: Differential Equations, spring 2020

MW 8:30-10:00, RLM 12.166

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In this course, the principles, analysis and applications of numerical approximations of differential equations will be presented. It is a continuation of M 387C - CSE 386K, Numerical Analysis: Algebra and Approximation from fall 2019 but it is self-contained, and the fall course is not necessary as a prerequisite. After a brief introduction we will study techniques for ordinary differential equations including differential algebraic and stochastic differential equations. The focus will then be on partial differential equations and the development and analysis of finite element and finite difference methods. Finite volume, discontinuous Galerkin, spectral, particle methods and algorithms for integral equations will also be considered but in less detail. The course will finish with applications to solid and fluid mechanics and to wave propagation.

We will often refer to the textbook: Quarteroni, Sacco, Saleri, Numerical Mathematics, https://sites.math.washington.edu/~morrow/464_17/sacco%20saleri%20numerical.pdf
There will also be handouts.

The grading will be based on homework 50% and final 50%.

Outline

- Fundamental principles in the numerical approximation of differential equations
- Algorithms for ODEs, initial and boundary value problems
- Development and analysis of the finite element method for PDEs
- Development and analysis of the finite difference method for PDEs
- Survey of finite volume, discontinuous Galerkin, spectral and particle methods
- Brief survey of numerical methods for integral equations
- Survey of techniques for solving algebraic equations from discretization of differential and integral equations
- Applications: Solid mechanics (finite element method)
  Fluid mechanics (finite volume method)
  Wave propagation (finite difference method)

General texts

A, Iserles, A First Course in the Numerical Analysis of Differential Equations, Cambridge, 1996
A. Quarteroni and A. Valli, Numerical Approximation of Partial Differential Equations, Spinger, 1997

Ordinary differential equations

E. Hairer, S.P. Norsett and G. Wanner, Solving Ordinary Differential Equations I: Nonstiff Problems, Springer, 1987
E. Hairer and G. Wanner, Solving Ordinary Differential Equations II: Stiff and Differential-Algebraic Problems, Springer, 2002
H. B. Keller Numerical Methods for Two-Point Boundary Value Problems, Blaisdell Publishing, 1968

Partial differential equations (finite element methods)

S. C. Brenner and L. R. Scott, The Mathematical Theory of Finite Element Methods, Springer, 2000

J. T. Oden, Finite Elements: A Second Course, Prentice Hall, 1983

Partial differential equations (finite difference methods)

R, D. Richtmyer and K. W. Morton, Difference methods for initial value problems, Wiley, 1967
B. Gustafsson, H.-O. Kreiss and J. Oliger, Time dependent problems and difference methods, Wiley, 1995

Partial differential equations (finite volume methods)

R. J. LeVeque, Finite volume methods for hyperbolic problems, Cambridge, 2002

Partial differential equations (pseudo spectral methods)

C.G. Canuto, M. Y. Hussaini, A. Quarteroni, and T.A. Zang, Spectral Methods: evolution to Complex Geometries and Applications to Fluid Dynamics, Springer, 2007