M 348: Scientific Computation in Numerical Analysis

The University of Texas at Austin, Fall 2023

Times: TuTh 12:30-2PM CT
Location: Face-to-face in PMA 5.118
Dates: 28 classes, Tu Aug 22 – Th Nov 30, with Tu Nov 21 and Th Nov 23 off
Supporting Media: Canvas
Registrar Information: Unique # 55615 and QR Flag

Instructor: Prof. Joe Kileel, jkileel@math.utexas.edu
Office Hours: MonWed 2-3PM CT in POB 3.434

Teaching Assistant: Gabriel Brown, ghbrown@utexas.edu
Office Hours: Fri 2:15-5:15PM CT in EER 5.704

Description: Solving scientific and engineering problems often requires the use of numerical methods and computers. This course teaches basic numerical methods, discusses their mathematical properties, and provides practice in computer programming. Topics include computer arithmetic, nonlinear algebraic equations, systems of linear algebraic equations, polynomial interpolation, numerical differentiation and integration, and initial value problems for ordinary differential equations.

Prerequisites: CS 303E (or any introductory programming course) and M 341 or 340L with a grade of at least C-.

Required Textbook: Timothy Sauer, Numerical Analysis, 3rd Ed., 2017, Pearson

Programming Language: The course's official programming languages are Matlab and Python. You are welcome to use either, although note that the textbook refers to Matlab. Matlab is free for UT students: `https://ut.service-now.com/sp?id=ut_bs_service_detail&sys_id=f9d65c7c4ff9d200f6897bcd0210c77d`. Python is open source: `https://www.python.org/`. Please confirm with the teaching assistant if you would like to use a different language. You may obtain a computer account on the Math network in the Undergraduate Computer Lab, PMA 7.122.

Homework: Homework and coding assignments will be assigned approximately weekly. It is permitted for students to work together in groups. However, each student must write up their own work individually.

Exams: Two 70-minute midterms will be held in class, tentatively on Thursday, September 21 and Thursday, October 26. A cumulative final exam will occur (tentatively) on Friday, December 8 at 8-10AM CT in PMA 5.118.

Final Grade: In determining final letter grades on the plus/minus scale, homework and coding assignments will count for 25%, each midterm will count for 20%, and the final exam will count for 35%. Your lowest homework score will be dropped. Letter grade cutoffs will be finalized after the final exam; however they will not be stricter than the following: A (100-90), A- (89-85), B+ (84-80), B (79-75), B- (74-70), C+ (69-65), C (64-61), C- (60-57), D (56-50), F (49-0). Throughout the semester, please check that your scores are recorded correctly in Canvas.

Tentative Course Plan: We will primarily study Chapters 0-3 and 5-6 of Sauer's book.

0. Fundamentals (~2 classes)
0.1. Evaluating a Polynomial
0.2. Binary Numbers
0.3. Floating Point Representation of Real Numbers
0.4. Loss of Significance

1. Solving Equations (~4.5 classes)
1.1. The Bisection Method
1.2. Fixed-Point Iteration
1.3. Limits of Accuracy
1.4. Newton's Method
1.5. Root-Finding without Derivatives
— Reality Check 1: Kinematics of the Stewart platform

2. Systems of Equations (~4.5 classes)
2.1. Gaussian Elimination
2.2. The LU Factorization
2.3. Sources of Error
2.4. The PA = LU Factorization
— Reality Check 2: The Euler-Bernoulli Beam

3. Interpolation (~5 classes)
3.1. Data and Interpolating Functions
3.2. Interpolation Error
3.3. Chebyshev Interpolation
3.4. Cubic Splines
— Reality Check 3: Fonts from Bezier curves

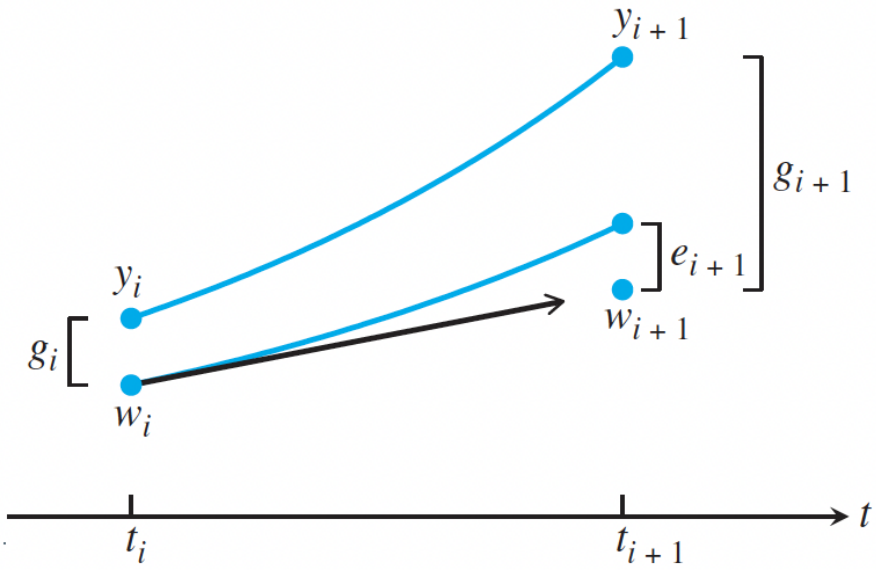
5. Numerical Differentiation and Integration (~5 classes)
5.1. Numerical Differentiation
5.2. Newton-Cotes Formulas for Numerical Integration
5.4. Adaptive Quadrature
5.5. Gaussian Quadrature
— Reality Check 5: Motion Control in Computer-Aided Modeling

6. Ordinary Differential Equations (~5 classes)
6.1. Initial Value Problems
6.2. Analysis of IVP Solvers
6.3. Systems of Ordinary Differential Equations
6.4. Runge-Kutta Methods and Applications
— Reality Check 6: The Tacoma Narrows Bridge
6.6. Implicit Methods and Stiff Equations

Guest Lectures: The first two lectures will be delivered by Yifan Zhang, yf.zhang@utexas.edu.

Accommodations: The University of Texas provides, upon request, academic accommodations for qualified students with disabilities. For more information, contact Services for Students with Disabilities at 512-471-6259 or ssd@austin.utexas.edu.

Student Honor Code: "As a student of The University of Texas at Austin, I shall abide by the core values of the University and uphold academic integrity."



A diagram illustrating what goes into the numerical analysis of an ordinary differential equation (ODE) solver. We will cover this topic towards the end of the course. *Image credit:* Sauer, 3rd edition, page 306.