CE 536 - Introduction to numerical methods for civil engineers
Summer 2024 (via taped lectures)

Description

This is an entry level graduate course intended to give an introduction to widely used numerical methods through application to several civil and environmental engineering problems. The emphasis will be on the breadth of topics and applications; however, to the extent possible, the mathematical theory behind the numerical methods will also be presented. The course is expected to lay foundation for students beginning to engage in their thesis projects that involve numerical methods. Student will use MATLAB as a tool in the course. Experience with MATLAB is not required. The course will be taught in an interactive setting in a computer equipped classroom.

Student Learning Outcomes

Upon completion of the course, the students will be able to:

- Describe and apply basic numerical methods for civil engineering problem solving.
- Develop algorithms and programs for solving civil engineering problems involving: (i) multi-dimensional integration, (ii) multivariate differentiation, (iii) ordinary differential equations, (iv) partial differential equations, (v) optimization, and (vi) curve fitting or inverse problems.

Course Schedule

Module	Topic	Relevant Lectures
1	**MATLAB Basics**	**Lectures 1-6**
1.1	General MATLAB commands and features (*Assignment 0*)	Lecture 1
1.2	Numeric arrays, Cell arrays, Structure Arrays	Lecture 2
1.3	Flow control, Scripts, and Functions	Lecture 3
1.4	Engineering Examples	Lectures 4-6
	Assignment 1 – Matlab basics	*Lectures 4-6*
	Quiz 0 (practice), Quiz 1 (Basics)	*Lecture 7*
2	**Numerical Integration and Differentiation**	**Lectures 7-12**
2.1	Numerical integration techniques and civil engineering applications – Newton-cotes formulas, line integrals, multi-dimensional integrals, integrating tabular data, Gauss-quadrature, Monte-Carlo integration	Lectures 7-11

	Assignment 2 – Numerical Integration methods with applications	*Lectures 7-11*
2.2	Numerical differentiation with engineering applications – Newton's difference formulas, higher order differentiation, multivariate differentiation, differentiation of tabular data	Lectures 11-13
	Quiz 2 (Numerical Integration)	*Lecture 13*
	Assignment 3 – Advanced numerical integration and differentiation with applications, Quiz 3	Lectures 9-13
3	**Ordinary differential equations**	**Lectures 13-20**
3.1	Initial value problems with applications in structural and environmental engineering - Runge-Kutta methods, Single ODEs, systems of ODES, higher order ODEs	Lectures 13- 16
3.2	Stiff systems with applications in environmental engineering	Lecture 17
3.3	Boundary value problems in structural and environmental engineering, Differential Algebraic Systems	Lectures 19-21
	Assignment 4 – ODE methods and applications, Quiz 4	*Lectures 13-21*
4	**Linear and non-linear system solution (direct and iterative methods)**	**Lectures 21-22**
4.1	Solving linear systems – Gaussian elimination, Gauss-Jordan, Iterative methods, applications	Lectures 21
4.2	Solving nonlinear systems – Newton-Raphson method, engineering applications	Lectures 22
	Assignment 5 – Linear and nonlinear systems	*Lectures 21 - 22*
5	**Partial differential equations**	**Lectures 23 - 25**
5.1	Finite-difference methods – elliptic, parabolic and hyperbolic systems, boundary conditions	Lecture 23
5.2	Applications in groundwater flow and transport	Lectures 24 - 25
5.2	Matlab PDE toolbox	Lecture 25
	Assignment 6 – PDE solution of groundwater applications	*Lectures 23 -25*
6	**Optimization**	**Lectures 26 - 28**
6.1	Example applications in environmental and structural engineering	Lecture 26
6.2	Gradient based methods with applications in structural and water resources engineering	Lectures 27
6.3	Heuristic methods with applications in water resources engineering	Lecture 28
6.4	Application case studies in structural and environmental engineering	Lectures 27-28
	Assignment 7 – Optimization applications in civil engineering	*Lectures 26 - 29*
7	**Curve fitting and inverse problems**	**Lectures 29 - 31**
7.1	Linear and non-linear regression with applications	Lecture 30

7.2	Direct and indirect methods with applications	Lecture 30-31
8	**Other features of MATLAB (GUI, Simulink, Mapping etc.)**	**Lecture 31**
	Mini-project – One dimensional groundwater flow equation with parameter fitting (Due 2 weeks from assigned date)	Lecture 31 (minute 7.5)
	Final Exam (Take Home; Comprehensive, Due 7 days from assigned date)	

Grading

A weighted average grade will be calculated as follows[1]: Assignments (50%), Mini-Project (20%), Final exam (30%). Lowest assignment grade will be dropped from the final grade calculation. +/- Grading system will be used.

Policies

Class attendance and full participation is expected of all students and university attendance regulations will be enforced as appropriate. Students shall adhere to the University's policy on academic integrity and classroom conduct found on the university's web site[2]**.** Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 515-7653. For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation[3].

Prerequisites

Graduate standing in engineering. MA 302 (or equivalent) or permission from instructor. Discuss with instructor for any clarification regarding these requirements. Undergraduate students should have a GPA of 3.0 or better and Junior standing.

Recommended (Hardcover book)

Chapra, S.C., and, R.P. Canale, **Numerical methods for engineers**, McGraw Hill, 6th/7th/8th Edition, 2010/2015/2020.

[1] Weighting subject to change within the ranges
[2] http://studentconduct.ncsu.edu/academic-integrity-an-overview
[3] http://dso.dasa.ncsu.edu/

Optional Texts:

Chapra, S.C. **Applied numerical methods with MATLAB for engineers and scientists**, 3rd edition, McGraw Hill, 2012.

Palm W.J. III, **Introduction to MATLAB 7 for engineers**, 2nd edition, McGraw Hill, 2005.

Schilling, R.J., and S.L. Harris, **Applied numerical methods for engineers using MATLAB and C**, Brooks/Cole Publishers, 2000.

Instructor (available via email and zoom)

Kumar Mahinthakumar
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(919) 515-7696
gmkumar@ncsu.edu.

Zoom personal link:

https://ncsu.zoom.us/my/**gmkumar**

Office Hours via Zoom (link is posted on moodle)

Tue 12:00 noon – 1:00 pm and Thu 4:00 – 5:00 pm

Join Zoom Meeting:

https://ncsu.zoom.us/j/91924228584?pwd=NlloZW5FRDFlenhRVUFqV0wyVVlPUT09

Teaching Assistant (available via email and zoom appointment)

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