ME964: Scientific Computing and Machine Learning for Engineering Application (Fall 2024)

Course Homepage
https://canvas.wisc.edu/courses/416929 (sign in through UW Canvas)

Time and Room
MW 3:30PM - 4:45PM, MECH ENGR 2108

Instructor
Prof. Wenxiao Pan
Office: ME 2242
Email: wpan9@wisc.edu
Office Hours: Friday 3:30-5:30PM (or by appointment)

Reference Materials:
1. Scientific Computing with MATLAB and Octave, Alfio Quarteroni, Fausto Saleri, and Paola Gervasio, Springer.
2. Scientific Computing. An Introductory Survey, Michael T. Heath, McGraw-Hill.
3. Journal articles and online resources provided in lecture notes.

Recommended Prerequisites
Calculus, Linear Algebra, Differential Equations, Probability, Statistics, and Computer Programming using Python and/or MATLAB

Course Description
This is a formal 700 level graduate-level course with 3 credits. It covers key topics in computing for engineering using both classical numerical approaches and machine learning techniques. As a formal course, there are regular lectures (twice weekly), homework assignments, and midterm/final projects. Computer programing is needed in both homework assignments and midterm/final projects.

Course Objectives
To develop an understanding in:
- Fundamental computational mathematics used in most fields of mechanical engineering
- Methods and results of numerical analysis
- Basic machine learning techniques for regression, learning dynamical systems, solving differential equations, and reduced-order modeling

To improve skills in:
- Problem solving using numerical techniques
- Implementation of numerical methods

Course Policies
- Attend lectures regularly.
- Homework and project assignments will be available on the course Canvas website. **Electronic submission (in PDF format)** is required and through Canvas. Late homework/project will NOT be graded.
- The homework and projects will be graded on completeness, correctness and style. Failure to present your results in a concise, easy to follow manner will result in deductions. Sufficient work needs to be shown to see how the results are obtained. Each student must turn in your own homework assignments

and projects and the work must be all your own (see Academic Misconduct statement below), but you are allowed to discuss with others while you are working on it.
- Materials sharing and course announcements will all be on Canvas.
- Any student who attempts to gain unfair advantage over other students on Academic Integrity will fail this course.

Evaluation and Grading

Homework	30% (10% for each)
Midterm I Project	20%
Midterm II Project	20%
Final Project	30%

Grading Scale:

Grades will be assigned as follows:

A	93-100%
AB	88 - 92%
B	83 - 87%
BC	78 - 82%
C	70 - 77%
D	60 - 69%
F	<60%

Diversity & Inclusion Statement

Diversity is a source of strength, creativity, and innovation for UW-Madison. We value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals. The University of Wisconsin-Madison fulfills its public mission by creating a welcoming and inclusive community for people from every background – people who as students, faculty, and staff serve Wisconsin and the world.

Academic Integrity Statement

By virtue of enrollment, each student agrees to uphold the high academic standards of the University of Wisconsin-Madison; academic misconduct is behavior that negatively impacts the integrity of the institution. Cheating, fabrication, plagiarism, unauthorized collaboration, and helping others commit these previously listed acts are examples of misconduct which may result in disciplinary action. Examples of disciplinary action include, but is not limited to, failure on the assignment/course, written reprimand, disciplinary probation, suspension, or expulsion.

Accommodations for Students with Disabilities Statement

The University of Wisconsin-Madison supports the right of all enrolled students to a full and equal educational opportunity. The Americans with Disabilities Act (ADA), Wisconsin State Statute (36.12), and UW-Madison policy (Faculty Document 1071) require that students with disabilities be reasonably accommodated in instruction and campus life. Reasonable accommodations for students with disabilities is a shared faculty and student responsibility. Students are expected to inform Prof. Pan of their need for instructional accommodations by the end of the third week of the semester, or as soon as possible after a disability has been incurred or recognized. Prof. Pan will work either directly with the student or in coordination with the McBurney Center to identify and provide reasonable instructional accommodations. Disability information, including instructional accommodations as part of a student's educational record, is confidential and protected under FERPA. (See: McBurney Disability Resource Center)

Privacy of Student Records & the Use of Audio Recorded Lectures Statement

Lecture materials and recordings for this course are protected intellectual property at UW-Madison. Students in this course may use the materials and recordings for their personal use related to participation in this class. Students may also take notes solely for their personal use. If a lecture is not already recorded, you are not authorized to record my lectures without my permission unless you are considered by the university to be a qualified student with a disability requiring accommodation. [Regent Policy Document 4-1] Students may not copy or have lecture materials and recordings outside of class, including posting on internet sites or selling to commercial entities. Students are also prohibited from providing or selling their personal notes to anyone else or being paid for taking notes by any person or commercial firm without the instructor's express written permission. Unauthorized use of these copyrighted lecture materials and recordings constitutes copyright infringement and may be addressed under the university's policies, UWS Chapters 14 and 17, governing student academic and non-academic misconduct.

Course Schedule: (subject to minor changes/updates)

#	Date	Day	Topic	HW Assigned
1	4-Sep	W	Introduction of Scientific Computing	
2	9-Sep	M	Interpolation-Polynomials	
3	11-Sep	W	Parametric Regression-Least Squares	
4	16-Sep	M	Deep Neural Networks-Basics	
5	18-Sep	W	Deep Neural Networks-Gradient Descent	HW1
6	23-Sep	M	Deep Neural Networks-Initialization, Hyperparameters	
7	25-Sep	W	Deep Neural Networks-Activation Function	
8	30-Sep	M	Multistage Neural Networks	
9	2-Oct	W	Non-parametric Regression-Gaussian Process	
10	7-Oct	M	Non-parametric Regression-Gaussian Process	
11	9-Oct	W	Non-parametric Regression-Gaussian Process	
	14-Oct	M	Integration-Simple Rules, Composite Rules	
12	16-Oct	W	**Midterm I Project Presentation**	HW2
13	21-Oct	M	Dynamical Systems-Basics, Learning by SINDy	
14	23-Oct	W	Numerical Methods for ODEs	
15	28-Oct	M	Numerical Methods for ODEs	
16	31-Oct	W	Learning Dynamical Systems-Neural ODE	
17	4-Nov	M	Linear Systems	
18	6-Nov	W	Linear Systems	
	11-Nov	M	Numerical Methods for Solving PDEs-Finite Difference	
19	13-Nov	W	**Midterm II Project Presentation**	HW3
20	18-Nov	M	Numerical Methods for Solving PDEs-PINN	
21	20-Nov	W	Reduced-order Modeling-SVD/POD, Galerkin Projection	
22	25-Nov	M	Reduced-order Modeling-Koopman Operator, Dynamical Mode Decomposition	
23	27-Nov	W	Explainable AI	
	2-Dec	M	**No class** (working on the final project)	
	4-Dec	W	**No class** (working on the final project)	
	9-Dec	M	**Final Project Presentation 1**	
	11-Dec	W	**Final Project Presentation 2**	