Syllabus, CEE 8813: Machine Learning in Structural Engineering (Fall 2026)

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About this class

Description: This course introduces core machine learning and artificial intelligence methods for structural engineering, mechanics and materials (SEMM). It covers forward prediction, inverse inference, pattern recognition, data-driven design, uncertainty-aware calibration, and model discovery, emphasizing surrogate and reduced-order modeling, physics-informed learning, modern deep learning approaches, and decision-making in SEMM.

The course is designed for M.S./Ph.D. students who want a thorough and practical introduction to machine learning for structural engineering. The class begins with the mathematical and computational foundations of machine learning, including supervised learning, optimization, neural networks, uncertainty concepts, and hands-on Python/PyTorch implementation. It then develops the connection between classical forward and inverse problems in structural engineering and modern data-driven methods.

Students will learn how machine learning can accelerate or augment structural analysis and design, with emphasis on surrogate modeling of finite element simulations, reduced-order models for linear and nonlinear systems, structural response prediction, data analysis for sensing and monitoring, ML-integrated optimization, and inverse problems arising in structural health monitoring (SHM) and nondestructive evaluation (NDE). The course also introduces conceptual structural design, uncertainty-aware model calibration, physics-informed learning, and modern deep learning workflows relevant to structural engineering, mechanics, and materials.

The following learning objectives will be realized:

- Understand the role of machine learning in structural engineering, mechanics, and materials, including how it complements physics-based modeling.
- Build and train machine learning models in Python and PyTorch for regression, classification, feature extraction, and inverse inference.
- Formulate forward and inverse problems in structural engineering and identify when data-driven, hybrid, or physics-informed approaches are appropriate.
- Develop surrogate and reduced-order models for finite element analysis, linear systems, and nonlinear structural response.
- Apply data analysis and pattern recognition methods to sensing, SHM, and NDE problems.
- Use machine learning together with optimization for model calibration, design-space exploration, and decision support.
- Critically evaluate model accuracy, generalization, interpretability, and uncertainty in engineering applications.

Pre-requisites/Co-requisites

Students should be comfortable with undergraduate-level calculus, linear algebra, and mechanics/structural analysis. Prior exposure to probability, numerical methods, and programming is helpful but not required. Students with limited Python experience will be supported during the early tutorial modules.

Textbook

There is no required textbook.

Course Components and Grading

This module will consist of the following components:

- Lectures (Th)
- Tutorials (built into lecture time, assignments are 25% of your grade)
- Midterm exam (25% of your grade)
- Final exam (25% of your grade)
- Project (25% of your grade)

Lectures
One lecture will be delivered per week. The tentative lecture plan is below.

Tutorials
This is a critical component of this class. The purpose of the tutorials is to get hands-on experience with machine learning for structural engineering in programming environments centered on Python and PyTorch. Students will work with numerical models, simulation data, and experimental or field-inspired datasets relevant to structures, mechanics, and materials. You will need a personal computer (e.g. laptop). While an NVIDIA video card (AMD video cards are not useful) in your computer is not necessary, it will help in speeding up ML implementations. **Assignments will be given during tutorial time and will be due at the beginning of class one week from the tutorial.**

Project
Each student will propose a project to Dr. Smyl of their choosing. The project should address a meaningful machine learning problem in structural engineering, mechanics, or materials. Projects may focus on surrogate modeling, inverse problems, SHM/NDE, uncertainty-aware model calibration, conceptual structural design, optimization, or other approved topics aligned with the course. Students are encouraged to combine sound engineering modeling with modern machine learning methodology.

Exams
The midterm and final exams will test your conceptual knowledge of all material covered up to the test point. The focus of the exams will not be procedural and may require derivations, interpretation of model behavior, comparison of methods, and writing pseudocode or algorithmic workflows.

Tentative Schedule

Week	Topic
1	Introduction to ML in structural engineering; course overview
2	Python and PyTorch foundations; optimization; training workflows
3	Core machine learning methods; regression; classification; cross-validation; model assessment
4	Forward problems in structural engineering; simulation pipelines; data generation
5	Neural network architectures; training dynamics; overfitting control; uncertainty awareness
6	Inverse problems in structural engineering; ill-posedness; regularization; uncertainty
7	Surrogate modeling of FEA; emulators for structural response; reduced-order representations
8	Surrogate modeling of linear and nonlinear systems; sequence models; operator learning
9	Data analysis for SEMM (*materials emphasis*); dimensionality reduction; anomaly detection
10	**Midterm exam**
11	ML-integrated optimization; exploration; calibration; Bayesian strategies
12	Physics-informed machine learning; PINNs; constraint-aware learning, UQ
13	Inverse problems in SHM and NDE; damage detection; localization; imaging/inference
14	Conceptual structural design with ML; generative ML
15	Project presentations

Supporting Resources

Mastering the material for this class while managing a full course load and maintaining your health can be challenging. Georgia Tech provides resources ranging from academic support to personal support, to health care. Some good places to start are the Center for Academic Success (success.gatech.edu), the counseling center (counseling.gatech.edu), and the health service (health.gatech.edu). **Please feel free to email me directly with any serious course concerns you may have, my ultimate aim as an educator is to see you succeed! I do my best to answer emails within 1 business day.**

Office of Disability Services

The Georgia Institute of Technology has policies regarding disability accommodation, which are administered through The Office of Disability Services. http://disabilityservices.gatech.edu/. For students with disabilities, please contact this Office to request accommodations.

Academic Integrity

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit http://www.catalog.gatech.edu/policies/honor-code/ or http://www.catalog.gatech.edu/rules/18/. Any student suspected of cheating or plagiarizing on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.