ENGN 2350: Data-Driven Design & Analysis of Structures & Materials (3dasm)

Miguel A. Bessa

Associate Professor, Brown University

E-mail: miguel_bessa@brown.edu
Instructor Office: Barus & Holley 731
Instructor Office Hours: TBD

Course webpage: Github Repository
Class Hours: MWF (3×50 min)
Class Room: TBD

Course Description

This course focuses on the data-driven design and analysis of structures and materials. The aim is to balance theory and practice, such that students understand and use data-driven methods in new scenarios. The first half of the course introduces machine learning from a probabilistic perspective, providing a foundation to understand current machine learning methods. The second part of the course focuses on applying the data-driven strategy to solve engineering problems. Although most examples covered will target solid mechanics applications, the content is applicable to different fields. The course is primarily lecture driven, but the lecture slides are interactive and include Python code that runs live.

Prerequisites

- Working knowledge of college-level calculus and linear algebra is required. Courses equivalent to MATH 0190, MATH 0200, and MATH 0520.
- Basic programming knowledge, preferably in Python, is required. However, a course equivalent to CSCI 0150 or CSCI 0170 is sufficient.

Prior coursework in statistics or probability (e.g. APMA 1650) is beneficial, but not strictly needed.

Required Textbooks

- Murphy, Kevin P. *Probabilistic machine learning: an introduction*. MIT press, 2022. Available online.

Recommended Textbooks

- Bishop, Christopher M. *Pattern recognition and machine learning*. Springer Verlag, 2006.
- Géron, Aurélien. *Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow*. O'Reilly Media, Inc., 2022.

Course Objectives

Upon completion of this course, students should be able to:

1. Understand, derive and analyze machine learning methods from a probabilistic perspective;
2. Understand basic sampling methods (design of experiments);
3. Understand basic optimization algorithms;
4. Identify appropriate sampling, data generation, machine learning, and optimization methods based on the application of interest;
5. Develop data-driven strategies for new problems.

Course Policies and Overall Expectations

Students in this course will be expected to do the following:

1. Attend all lectures and actively participate in discussion;
2. **Optionally**, bring laptop to the lectures because slides include interactive Python code that can be run live (however, bringing laptop is not required);
3. Read all assigned materials as indicated at the beginning of each lecture.
4. Complete and turn in all assignments on time. Solutions to homework must be clearly written with appropriate tables and figures included.
5. Demonstrate an understanding of course content on the midterm examination and the final project.
6. Respect each other, including questions posed by others and corresponding discussion.

Evaluation

Students will be evaluated based on:

Grade Category	Percentage
Homework	30%
Midterm Exam	30%
Final Project	40%

Evaluation Category Details

Homework. Homework assignments will be graded only with 5 levels: A+ (100%; fully correct), A (90%; has minor error), B (75%; has significant error or several minor errors), C (60%; several significant errors), D (0%, homework not delivered). If you deliver something with an honest attempt at solving the homework you are assigned 60% for that homework. Late Homework can only get up to A (90%). The worst Homework is removed.

Midterm Exam. Midterm will be in class, and will cover materials presented in lectures, readings and assignments. The midterm is closed-book. As a general rule, make up exams and advance exams will not be given, with the exception when the dates conflict with religious observances or truly exceptional circumstance. Please let me know ahead of time if you need to make alternative arrangements for this purpose.

Final Project. The Final Project involves using the data-driven strategy to solve a simple Engineering problem. Teams cannot have more than 2 group members (individual projects are possible, but are graded similarly). Each group needs to have a project defined by the end of the week that follows the midterm, **including feedback provided by the instructors**. If the project is not defined and the instructors have not agreed with the project proposal before that deadline, then the group is assigned one of the **predefined projects**. The project deliverables include a mandatory report (PDF) and the necessary code to generate all the results (a single ZIP folder). The report needs to explain the methods used, the reasoning behind method selection, and results. The code needs to be properly commented and it must be possible to run it without modifications.

Time Allocation

This course is a one credit course, amounting to 180 hours of in-class and out-of-class work over the semester as listed below.

Task	Hours Spent on Task
Thirty-six 50-minute lectures	30
Reading (lectures and book)	30
Six regular homework assignments[1]	36
One midterm exam (in class; 36 h to study)	36
Final Project	48
Total	180

Class Schedule

A detailed schedule is available on the course webpage.

[1] Estimate includes time in office hours which should reduce total time to complete problems, and assumes part of your usual preparation for solving problems is captured in the reading time estimate

Accessibility and Accommodations Statement

Brown University is committed to full inclusion of all students. Please inform the professor early in the term if you may require accommodations or modification of any course procedures. You may speak with the professor after class, during office hours, or by appointment. If you need accommodations around online learning or in classroom accommodations, please be sure to reach out to Student Accessibility Services (SAS) for their assistance (sas@brown.edu, 401-863-9588). Undergraduates in need of short-term academic advice or support can contact an academic dean in the College by emailing college@brown.edu. Graduate students may contact one of the deans in the Graduate School by emailing graduate_school@brown.edu.

Diversity Statement

This course is designed to support an inclusive learning environment where diverse perspectives are recognized, respected and seen as a source of strength. It is our intent to provide materials and activities that are respectful of various levels of diversity: mathematical background, previous computing skills, gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

English Language Learners

Brown University welcomes students from around the world, and the unique perspectives international students bring enrich the campus community. To empower students whose first language is not English, an array of ELL support is available on campus including language and culture workshops and individual appointments. For more information about English Language Learning at Brown, contact the ELL Specialists at ellwriting@brown.edu.