

# Machine Learning Applications in Civil Engineering

EGN 5215

**Class Periods:** T, R | Period 5 - 6

**Location:** BLK 0213

**Academic Term:** Spring 2022

## **Instructor:**

Professor Xilei Zhao

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Office Hours: by appointment @ Weil Hall 504

## **Course Description:**

EGN 5212 Machine Learning Applications in Civil Engineering

3 Credits

Students will leverage state-of-the-art techniques and tools in machine learning to solve Civil Engineering problems. Fundamentals of data analytics and machine learning techniques will be applied to real-world tasks in Civil Engineering. Students will gain essential knowledge and programming skills (using R) in data preprocessing, feature selection, model comparison, hyperparameter tuning and machine-learning interpretation. Case studies and applications are included for hands-on experience.

## **Course Pre-Requisites / Co-Requisites:**

Undergraduate level courses in probability/statistics and programming.

**Grading Scheme:** Letter Grade

## **Course Objectives:**

After taking this course, the students will be able to:

- Identify potential applications of machine learning in Civil Engineering
- Select appropriate machine-learning techniques for a Civil Engineering application
- Apply popular algorithms in supervised and unsupervised learning
- Analyze model performance using relevant error metrics for different applications
- Interpret machine-learning models to gain insights for decision making
- Implement these techniques and tools in R

## **Required Textbooks and Software:**

- **An Introduction to Statistical Learning: with Applications in R (Springer Texts in Statistics)**
- Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani
- 2nd ed. 2021 Edition
- ISBN-13: 978-1071614174
- Software: R (open-source software)
- Online available at: <https://www.statlearning.com/>

### **Recommended Materials:**

- **Interpretable Machine Learning**

Christoph Molnar

March 24, 2019, 1st edition

ISBN 9780244768522

Online available at: <https://christophm.github.io/interpretable-ml-book/>

- **The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Second Edition (Springer Series in Statistics)**

Trevor Hastie, Robert Tibshirani, Jerome Friedman

ISBN-13: 978-0387848570

Online available at: [https://web.stanford.edu/~hastie/ElemStatLearn/printings/ESLII\\_print12.pdf](https://web.stanford.edu/~hastie/ElemStatLearn/printings/ESLII_print12.pdf)

### **Course Schedule:**

- Week 1: Overview of machine-learning applications in Civil Engineering; fundamentals of data science and machine learning
- Week 2: Data preprocessing techniques: Missing data imputation and multicollinearity (VIF and PCA)
- Week 3: Feature selection techniques: Ridge, Lasso, and best-subset selection
- Week 4: **Lab 1:** Apply data preprocessing and feature selection techniques to travel mode choice data (a classification problem) and disaster risk assessment data (a regression problem) using R/**Quiz**
- Week 5: Concept of bias-variance tradeoff; model comparison methods: AIC/BIC, adjusted R-squared, cross validation, and holdout test; model performance metrics: MSE, MAE, accuracy, and AUC
- Week 6: Fundamentals of machine-learning models – Part 1: linear regression, logistic regression, naïve Bayes
- Week 7: **Lab 2:** Implement abovementioned machine-learning algorithms for travel mode choice data and disaster risk assessment data using R/**Quiz**
- Week 8: Fundamentals of machine-learning models – Part 2: support vector machine and classification and regression trees, boosting trees, bagging trees, and random forest
- Week 9: Fundamentals of machine-learning models – Part 3: artificial neural networks
- Week 10: **Lab 3:** Compare multiple machine-learning algorithms and identify best-performing models for travel mode choice data and disaster risk assessment data using R
- Week 11-12: Interpretable machine learning – Part 1: variable importance, partial dependence plot, accumulated local effects plot, and individual conditional expectation plot/**Midterm exam**
- Week 13: Interpretable machine learning – Part 2: model distillation, global surrogate, and local surrogate
- Week 14: **Lab 4:** Apply interpretable machine learning tools to extract insights from black-box models for travel mode choice data and disaster risk assessment data using R
- Week 15: Term project preparation and discussion

### **Online Course Recording**

Our class sessions may be audio visually recorded for students in the class to refer back and for enrolled students who are unable to attend live. Students who participate with their camera engaged or utilize a profile image are agreeing to have their video or image recorded. If you are unwilling to consent to have your profile or video image recorded, be sure to keep your camera off and do not use a profile image. Likewise, students who un-mute during class and participate orally are agreeing to have their voices recorded. If you are not willing to consent to have your voice recorded during class, you will need to keep your mute button activated and communicate exclusively using the "chat" feature, which allows students to type questions and comments live. The chat will not be recorded or shared. As in all courses, unauthorized recording and unauthorized sharing of recorded materials is prohibited.

### **In-Class Recording**

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil

proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A “class lecture” is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To “publish” means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

***Attendance Policy, Class Expectations, and Make-Up Policy:***

Students are not required to attend the lectures and labs in person but encouraged to do so. Please come to class prepared to ask and answer questions and actively participate in group discussions.

All the homework assignments will be based on the content covered in class and/or reading materials. Collaborating with others is fine as long as you finish and turn in your own assignment. **Copying of other’s work is plagiarism and will not be allowed.** Homework assignments must be turned in at the beginning of the class on the due date. Late submissions will not be accepted, except under special circumstances or when prior permission has been sought.

There will be two quizzes and one midterm exam. The quizzes and midterm exam will be open-book. Requests for make-up quizzes and exam are strongly discouraged. Such requests will be accommodated only under special circumstances and when prior permission from the instructor has been sought adequately in advance.

Term project will be conducted by team of 2~3 people. A term project report must be submitted by the due date. Late submissions will not be accepted, except under special circumstances or when prior permission has been sought. In the report, all the information extracted from external references must be cited. **An author contribution statement** must be included in the end of the report, by specifying the contributions of each team member in terms of study conception and design, data collection, modeling and software development, analysis and interpretation of results, and report preparation. The term project will be presented in class during the final exam period (4/26/2022 @ 7:30 AM - 9:30 AM).

Excused absences must be in compliance with university policies in the Graduate Catalog (<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#attendance>) and require appropriate documentation.

***Evaluation of Grades:***

Assignment	Total Points	Percentage of Final Grade
Homework Sets (5)	100 each	25%
Quizzes (2)	100 each	15%
Midterm Exam	100	30%
Term Project	100	30%
		100%

**Grading Policy:**

Percent	Grade	Grade Points
90.0 - 100.0	A	4.00
87.0 - 89.9	A-	3.67
84.0 - 86.9	B+	3.33
81.0 - 83.9	B	3.00
78.0 - 80.9	B-	2.67
75.0 - 77.9	C+	2.33
72.0 - 74.9	C	2.00
69.0 - 71.9	C-	1.67
66.0 - 68.9	D+	1.33
63.0 - 65.9	D	1.00
60.0 - 62.9	D-	0.67
0 - 59.9	E	0.00

More information on UF grading policy may be found at:

<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades>

**Students Requiring Accommodations:**

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting <https://disability.ufl.edu/students/get-started/>. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

**Course Evaluation:**

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.aa.ufl.edu/students/>. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via <https://ufl.bluera.com/ufl/>. Summaries of course evaluation results are available to students at <https://gatorevals.aa.ufl.edu/public-results/>.

**University Honesty Policy:**

UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (<https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

**Commitment to a Safe and Inclusive Learning Environment:**

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Robin Bielling, Director of Human Resources, 352-392-0903, [rbielling@eng.ufl.edu](mailto:rbielling@eng.ufl.edu)
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, [taylor@eng.ufl.edu](mailto:taylor@eng.ufl.edu)
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, [nishida@eng.ufl.edu](mailto:nishida@eng.ufl.edu)

### ***Software Use:***

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

### ***Student Privacy:***

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: <https://registrar.ufl.edu/ferpa.html>

### ***Campus Resources:***

#### *Health and Wellness:*

#### **U Matter, We Care:**

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact [umatter@ufl.edu](mailto:umatter@ufl.edu) so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

**Counseling and Wellness Center:** <http://www.counseling.ufl.edu/cwc>, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

#### **Sexual Discrimination, Harassment, Assault, or Violence**

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, [title-ix@ufl.edu](mailto:title-ix@ufl.edu)

#### **Sexual Assault Recovery Services (SARS)**

Student Health Care Center, 392-1161.

**University Police Department** at 392-1111 (or 9-1-1 for emergencies), or <http://www.police.ufl.edu/>.

Academic Resources:

**E-learning technical support**, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu.  
<https://lss.at.ufl.edu/help.shtml>.

**Career Resource Center**, Reitz Union, 392-1601. Career assistance and counseling. <https://www.crc.ufl.edu/>.

**Library Support**, <http://cms.uflib.ufl.edu/ask>. Various ways to receive assistance with respect to using the libraries or finding resources.

**Teaching Center**, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.  
<https://teachingcenter.ufl.edu/>.

**Writing Studio, 302 Tigert Hall**, 846-1138. Help brainstorming, formatting, and writing papers.  
<https://writing.ufl.edu/writing-studio/>.

**Student Complaints Campus:** <https://care.dso.ufl.edu>.

**On-Line Students Complaints:** <http://www.distance.ufl.edu/student-complaint-process>.