ASEN 6337 Remote Sensing Data Analysis

The material outlined in this syllabus is preliminary and subject to change.

Lectures: M/W 1:00-2:15pm, AERO 232
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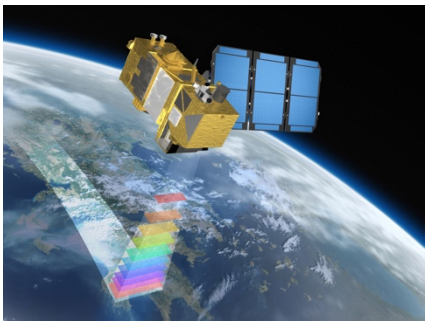

Course Description

With an explosive increase in the availability of high-resolution earth and space remote sensing data, analyzing it has become a big data problem. Increasingly, machine learning is being recognized as a powerful tool for addressing this challenge. This course covers some of the most commonly used machine learning techniques in remote sensing data analysis, specifically for clustering, classification, feature extraction and dimensionality reduction. The course also covers inverse methods used to retrieve geophysical information from remote sensing data. The course materials are organized into five sections: (1) Introduction, (2) Feature Extraction and Selection, (3) Clustering, (4) Classification, and (5) Inverse Methods for Atmospheric Remote Sensing Data. Hands-on computational homework (in Matlab or/and Python) and group and individual projects provide opportunities to apply classroom curricula to real remote sensing data.

Class Learning Goals

The goal of this course is to introduce commonly used machine learning techniques and inverse methods in remote sensing data analysis, equipping students with the knowledge and skills to apply modern data analysis techniques to remotely sensed data on their own. Students will: (1) develop a deeper understanding of machine learning and inverse methods in the context of remote sensing data analysis; (2) actively apply their own understanding of the fundamentals and tradeoffs of different approaches in critiquing current remote sensing data analysis research; and (3) develop the skills, confidence and creativity to design and solve a remote sensing data analysis problem of their choice.

Prerequisites

Some basic understanding of estimation theory and statistical learning techniques (e.g., ASEN 5044 Statistical Estimation for Dynamical Systems, ASEN 5307 Engineering Data Analysis Methods), as well as programming experience with Matlab or/and Python and familiarity with software engineering tools (e.g., Git) are desired.

Course Content

The class is broken into several sections, as follows:

- **Section 1: Introduction (Week 1-2)**
  - **Fundamentals of Remote Sensing**
  - **Remote Sensing Data Collection**
  - **Data Analysis and Statistical Learning Techniques**

- **Section 2: Feature Extraction and Selection (Week 2-3)**
  - **Principal Component Analysis**
  - **Kernel Methods**

- **Section 3: Clustering (Week 4-5)**
  - **K-Means**

  - **Iterative Self-Organizing Data Analysis Technique**
  - **Hierarchical Clustering**

- **Section 4: Classification (Week 5-9)**
  - **Bayesian classification**
  - **Neural Networks**
  - **Support Vector Machines**
  - **Tree Structured Classifier**
  - **Bragging and Random Forest**

- **Section 5: Inversion Methods for Remote Sensing Data (Week 10-11)**
  - **Overview of Inverse Problem**
  - **Information Content of Measurements**
  - **Applications to Atmospheric and Other Geophysical Remote Sensing Data**

- **Section 6: Uncertainty Quantification (Week 11)**

- **Group/Individual Project Lab & Presentation (Week 13-15)**

Texts

All the reading material required for the course will be provided through the Canvas course webpage. Suggested (not required) text books on the topics covered in this course include:

- Remote Sensing Handbook, edited by Thenkabail (2015) - *eBook at CU library*
- Introductory Digital Image Processing: A Remote Sensing Perspective, 4th ed, Jensen (2015) - *on reserve*
- Remote Sensing Digital Image Analysis, Richards (2013) - *eBook at CU library*
- Pattern Recognition and Machine Learning, Bishop (2006) - *PDF available from https://www.microsoft.com/en-us/research/uploads/prod/2006/01/Bishop-Pattern-Recognition-and-Machine-Learning-2006.pdf*
- An Introduction to Statistical Learning, James (2013) - *eBook at CU library*
- Kernel Methods for Remote Sensing Data Analysis, edited by Camp-Valls and Bruzzone (2009) - *eBook at CU library*
- Inverse Methods for Atmospheric Sounding: Theory and Practice, Rodgers (2000) - *eBook at CU library*
- Occultations for Probing Atmosphere and Climate, edited by Kirchengast, Foelsche and Steiner (2004) - *eBook at CU library*

Class Format

The course will involve weekly lectures on the course content outlined above, as well as discussions of several key research articles. Homework assignments will provide opportunities to apply the data analysis techniques to real remote sensing data. A midterm take-home exam will be given to assess students' understanding and progress. Group and Individual projects will be required. Final oral and poster presentations of each student's project will be evaluated in terms of the soundness of a problem formulation, the quality and effort of research and analysis, the quality and clarity of oral and written presentations as well as the contributions to group work. Students are also asked to participate in peer evaluation of the oral presentations as part of the final project evaluation.

Course Grading

5%	Participation (e.g., student's goal statement, weekly feedback and self-assessment)
30%	Homework (3 assignments; For each assignment, students will be randomly selected for a code interview)
15%	Midterm exam (close book and notes, no computer or phone)
25%	Group project (10% oral presentation,15% written report; Individual grades prorated by group peer-evaluation)
25%	Individual project (10% oral presentation, 15% poster, and 5% peer-evaluation)
100%	Total

Late work is **NOT** accepted unless prior arrangements (at least one week in advance) have been made with the instructor

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the Honor Code may include but are not limited to: plagiarism (including use of paper writing services or technology [such as essay bots]), cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. Understanding the course's syllabus is a vital part of adhering to the Honor Code. All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution: StudentConduct@colorado.edu. Students found responsible for violating the Honor Code will be assigned resolution outcomes from Student Conduct & Conflict Resolution and will be subject to academic sanctions from the faculty member. Visit Honor Code for more information on the academic integrity policy.

Acceptable Use of AI in This Class

You may use GenAI tools on assignments in this course, but their use is limited to the following particular tasks: for example, you may use them for grammar checks, but not for generating original ideas or outlines for written reports; you may use them to look up or understand an algorithm, but not to generate code for an assignment. Note that, for each assignment, students will be randomly selected for a code interview to demonstrate their understanding and earn the assignment points. The final work must be student-generated, summarizing or synthesizing research, with proper critical evaluation and original analysis. If you use gen AI tools on assignments in this class, document your usage with the Chicago Manual of Style or appropriate citation guidelines specified for each assignment.

Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or DSinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website. If you have a temporary illness, injury or required medical isolation for which you require adjustment, contact the instructor by email as soon as possible. You do not need to state the nature of your illness or provide a doctor's note, but you are required to provide cation in advance. There is no need to notify your absence from lectures.

Religious Accommodations

Instructional faculty members must make every reasonable effort to accommodate all students who have conflicts with scheduled exams, assignment deadlines or required attendance due to a religious observance. Whenever possible, students must notify the instructional faculty member at least two weeks in advance of the expected exam, assignment deadline, or attendance conflict to request an accommodation for religious observance. If the start date of the course is less than two weeks before the date of requested accommodation, students must notify the instructional faculty member on the start date of the course. See the Student Academic Accommodations for Religious Observances Policy for more information.

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information does not always align with how they identify. If you wish to have a name other than your legal name appear on your instructors' class rosters and in Canvas, or if you wish to choose pronouns to appear on your instructors' class rosters and in Canvas, visit the Registrar's website for instructions on how to change your personal information in university systems.

Classroom Behavior

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, marital status, political affiliation, or political philosophy. Additional classroom behavior information: Student Classroom and Course-Related Behavior Policy, Student Code of Conduct, Office of Institutional Equity and Compliance.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering a productive and welcoming learning, working, and living environment. University policy prohibits protected-class discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner abuse (dating or domestic violence), stalking, and related retaliation by or against members of our community on- or off-campus. Denial of an approved accommodation for disability, religious observance, or pregnancy or pregnancy related medical conditions may be discriminatory. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who have been subjected to misconduct can contact OIEC at 303-492-2127 or email OIEC@colorado.edu. Information about university policies, OIEC reporting options, and OIEC support resources including confidential services can be found on the OIEC website. Faculty and graduate instructors are required to inform OIEC when someone discloses misconduct regardless of when or where it occurred. This is to ensure that those impacted receive outreach from OIEC about resolution options and support resources. To learn more about reporting and support options for a variety of concerns, visit the Don't Ignore It page.

Mental Health and Wellness

The University of Colorado Boulder is committed to supporting students' mental health and overall wellbeing. If personal, academic, or emotional challenges are affecting your wellbeing or success, Counseling and Psychiatric Services (CAPS), is here to help. CAPS offers counseling, referrals, psychiatric care, crisis support, and much more. Visit CAPS in the C4C, or call (303) 492-2277, 24/7.