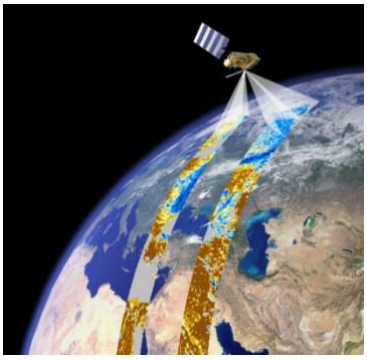
ASEN 6337 Remote Sensing Data Analysis



Lecture: T/TH 11:30-12:45pm, AERO 232
Webpage: Canvas (https://canvas.colorado.edu)
Instructor: Prof. Tomoko Matsuo
Office Hour: T/TH 12:45-1:45pm, or by appointment, AERO 467
E-mail: tomoko.matsuo@colorado.edu
(Note that the Canvas Conversations communication tool is not used)

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 a number of 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)**
  - **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 Atmospheric Remote Sensing Data (Week 10-11)**
  - **Abel Transform and Inversion**
  - **Review of Radiative Transfer, Weighting Functions, Averaging Kernels**
  - **Bayesian and Variational Methods**
  - **Temperature Profile Inversion**

- **Section 6: Uncertainty Quantification (Week 12)**

- **Group Project Lab & Final Project Lab (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*

You can access these books as eBook from the CU library website, or on reserve in the Bartlett Center (SEEC C215).

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 written reports 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 reviews of the oral presentations as part of the final project evaluation.

Course Grading

7%	Participation (e.g., student's goal statement, weekly feedback and self-assessment, peer-reviews)
28%	Homework (4 assignments)
20%	Midterm take-home exam
15%	Group project (5% oral presentation & 10% written report, prorated by peer-evaluation)
30%	Individual project (10% oral/virtual poster presentation and 20% written report)
100%	Total

Late work is **NOT** accepted. There will be one 'makeup' homework opportunity at the end of semester.

Disabilities

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to me 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 or injury, see Temporary Medical Conditions under the Students tab on the Disability Services website.

Classroom Behavior

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail 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, political affiliation or political philosophy. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. For more information, see the policies on Classroom Behavior and the Student Code of Conduct.

Academic 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 policy may include: plagiarism, 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. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu; 303-492-5550). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the Honor Code Office website. Violations of the Honor Code include any act of **academic dishonesty** which is defined as follows. Any act in which a student gains, or attempts to gain, an unfair academic advantage over other students. These acts may include, but are not limited to:

I. **Plagiarism:** Portrayal of another's work or ideas as one's own.
II. **Cheating:** Using prohibited notes or study aids, allowing another party to do one's work/exam and turning in that work/exam as one's own, copying another student's course work, and collaborating on course work when prohibited.
III. **Fabrication:** Falsification or creation of data, research, or resources, altering a graded work without the prior consent of the course instructor.
IV. **Lying:** Deliberate falsification with the intent to deceive in written or verbal form as applied to an academic submission.

V. **Bribery:** Providing, offering, or taking rewards in exchange for a grade, or, an assignment, or in the aid of Academic Dishonesty.

VI. **Threat:** An attempt to intimidate a student, staff, or faculty member for the purpose of receiving an unearned grade or in an effort to prevent the reporting of an Honor Code violation, or in connection with any other form of Academic Dishonesty.

VII. **Unauthorized Access:** Gaining unauthorized access to protected academic information including, but not limited to: CU-SIS; a faculty member's computer, files, and/or office; or secure information on an online server.

VIII. **Clicker Fraud:** Using, or having someone else use, clicker technology fraudulently in an effort to receive academic credit.

IX. **Resubmission:** Submitting the same or similar work for credit more than once without permission from all course instructors involved.

X. **Aiding Academic Dishonesty:** Intentionally facilitating any act which may help a student to gain an unfair academic advantage including, but not limited to, any of the aforementioned acts.

Any act of academic dishonesty will result in an F for this course and will become a permanent part of the student's academic record.

Plagiarism

This course includes a research project and final written report. In constructing the research paper it is expected that ideas and concepts will come from specific reference material. It must be demonstrated that this material supports the original premise of your research project and is properly referenced. Please examine the following guidelines to avoid committing plagiarism:

How to avoid plagiarism, Northwestern University
Plagiarism: What it is and how to recognize and avoid it, Indiana University

Misconduct, Discrimination, Harassment and/or Related Retaliation

The University of Colorado Boulder (CU Boulder) is committed to fostering a positive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (including sexual assault, exploitation, harassment, dating or domestic violence, and stalking), discrimination, and harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or cureport@colorado.edu. Information about the OIEC, university policies, anonymous reporting, and the campus resources can be found on the OIEC website. Please know that faculty and instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

Other Policies

Please be respectful of others during class time. This includes turning off your cell phone before class and not talking during class unless you have the floor. Details about all of the university policies can be found on the web at http://www.colorado.edu/policies/index.htm

Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to reasonably and fairly deal with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, all dates for exams, assignments and presentations are listed in the course schedule. Please review the course schedule and let me know if certain dates conflict with your religious obligations. See the campus policy regarding religious observances for full details.