Remote Sensing Systems and Advanced Analytics

Location: ENF 304
Thursday 12pm - 1:30pm
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Course Description:

This reading course focuses on the quantitative and physical aspects of remote sensing systems, advanced deep learning and inverse modeling techniques for solving remote sensing inverse problems, and environmental monitoring applications, e.g., SAR Pan-Arctic sea ice mapping, Arctic species detection, crop bio-parameter retrieval and hyperspectral environmental mapping. Topics include:

- Remote sensing system overview
- Key remote sensing techniques, i.e., synthetic aperture radar, hyperspectral, multispectral, LiDAR, and passive microwave.
- Remote sensing radiation and radiative transfer equation
- Popular radiative transfer models (RTMs) for crop, canopy, ice and snow, e.g., PROSPECT, SAIL, PROSAIL, and SMRT.
- Approaches for solving inverse problems, e.g., LUT, Bayesian methods, machine learning methods, hybrid approaches
- Introduction to deep learning methods, e.g., CNN, Transformers, neural radiative field (NeRF) and Gaussian splatting.
- Hyperspectral image classification and spectral unmixing analysis
- SAR image classification for sea ice mapping
- Biochemical and biophysical parameter retrieval from PROSAIL model
- How to integrate knowledge-driven RTMs into NeRF to achieve hybrid models.
- Solving PROSAIL model using deep learning approaches

Tentative Class Schedule:

Week 1 - Introduction and overview
Week 2 - Radiation and radiative transfer equations in remote sensing systems
Week 3 - Microwave, Thermal, Lidar and Optical remote sensing systems
Week 4 - Leaf, canopy, snow and ice radiative transfer models (RTM)
Week 5 - Presentation of course project proposals
Week 6 - Approaches for solving inverse problems
Week 7 - No class due to reading week

Week 8 - Biochemical and biophysical parameter retrieval from RTM models
Week 9 - Introduction to deep learning methods
Week 10. Physics-informed AI to integrate knowledge into deep learning models
Week 11 - Deep learning methods for hyperspectral image classification and spectral unmixing
Week 12 - Deep learning methods for SAR sea ice classification
Week 13 - Presentation of final projects
End of Week 14. - Project papers due

Course Learning Goals:

➔ Understand fundamentals of different remote sensing techniques
➔ Understand the physical principles (i.e., radiative transfer models) underlying remote sensing systems.
➔ Develop expertise in applying appropriate image processing and data inversion techniques to extract environmental parameters in selected applications (e.g., land cover classification, sea ice mapping, water pollution mapping, crop biochemical/biophysical parameter retrieval).
➔ Evaluate uncertainties/errors in remote sensing systems and results.
➔ Learn to use standard remote sensing image processing pipeline and processing tools
➔ Develop active learning and creative thinking capability through project presentations and term paper

Grading Criteria:

- **Lecture attendance and participation: 15%**

Lecture and lab attendance and discussion participation has 15% weight. The students need to ensure attendance for both lab and lecture, and actively participate in answer equations and course discussion. This 15% is designed to promote participation and discussion during class and lab. Actively engaging in discussion can better help the students to understand key concepts and theory in the class. It can also better help students to develop active learning and critical thinking capabilities.

- **Lab assignments: 30%**

We have the following lab assignments:

Lab 1: Comparing different approaches for solving inverse problems (7%)
Lab 2: Biochemical and biophysical parameter retrieval from PROSAIL model (7%)
Lab 3: Cloud-based processing – the Google Earth Engine environment (7%)
Lab 4: Advanced classification and bio-parameters retrieval using deep learning (9%)

Lab assignments are due at the beginning of the following week's lab. The penalty for assignments handed in late is 20% per day every day after. All lab assignments must be submitted to be allowed to sit the final examination. Failure to submit a lab assignment will result in a failing grade of incomplete (N). Exceptions will only be granted for medical reasons (requiring a written report from a medical practitioner stating your inability to attend the class).

- **Presentations 15%**

In the first presentation, you will have about 10 min to talk about your course project, you are expected to talk about what are the variables that you want to estimate, what are the remote sensing data you are going to use, are there forward models? What are the assumptions of the model, does it have bias or uncertainties? What are the approaches that are feasible to solve the problem? The audience and I will give you feedback on your project. Then, in the ninth week and the tenth week, you are required to talk with me again about the progress of the project. I hope to know how I and the TA can help you to make sure the project goes well. The final presentation will be focused on presenting the results of the project and conclusions.

- **Term paper: 40%**

The term paper is due at the end of the 14th week. The format and requirement of this paper is consistent with the journal paper in remote sensing. Its structure is supposed to follow a journal paper format, with abstract, introduction, methodology, result, discussion and conclusions, and references.There are some minimum requirements in terms of length, minimum length is 10 pages for double line spacing or under, font size of 12 or under. The grading criteria is based on how much the paper looks like a journal paper in terms of structure, format, length, novelty and quality of writing.