Artificial Intelligence for Science and Technology

a.a. 2024/2025

Physical Sensors and Systems for Environmental Imaging/Signal

Remote Sensing

Prof. Cogliati / Prof.ssa Sironi

Content

1. Final examination

2. Thesis Proposal

Final examination

Final examination – Remote Sensing

Projects to prepare for the two courses

Students	Course			
	Imaging		Signal	
	Cogliati (remote sensing)	Sironi (remote sensing)	Cogliati (remote sensing)	Nutini (acoustic / seismic)
Imaging	1 project (5 pags)			
Signal			1 short project spectroscopy and RT models (3 pags)	1 short project (3 pags)
Imaging + Signal	1 larger project (7 pags)			1 short project (3 pags)

Final examination

Project Development

- Students are required to develop a concise “project” and present it for discussion, addressing theoretical questions related to the project topics as well as broader concepts covered during the course.
- A short report with text and figures in Word or PDF format, approximately 5 pages long, including figures. The report should be structured like a scientific manuscript with the following sections: (i) Introduction; (ii) Methods and Data; (iii) Results; (iv) Discussion and Conclusions.
- The report should be self-explanatory! Providing computer implementation code or other technical materials is not mandatory, but you are welcome to include them if desired as they will be appreciated.
- We suggest starting with the conceptualization of the project you wish to undertake and sending us a five-line description of the project by email. This will allow us to provide you with feedback before you begin your work.
- Students may use any suitable tools such as ENVI (Lab. Virtual Machine), MATLAB, Python, Excel, or others as needed, there are no restrictions (cit. "The end justifies the means.")

Final examination

Presentation / Discussion Guidelines

- Scheduling:
  - The exam date should be agreed upon in advance, typically after significant progress has been made on the project and a clear timeline for submission of the doc/pdf is clearer.
  - We do not require you to adhere strictly to the official examination dates because we aim to provide you with greater flexibility in preparing your project! Instead, we will allocate approximately one day per month for examinations. We kindly request that you coordinate among yourselves to propose a date on which 3–5 students can take the exam on the same day.
- Deadline: The project must be submitted at least 5-7 days before the examination date.
- Presentation: it is not mandatory, but we encourage preparing PowerPoint slides to effectively communicate your work by summarizing the objectives, methodology and data used, key results, and discussion/conclusion points (approximately 10 slides)

Final examination

Assessment criteria

- Knowledge of remote sensing fundamentals covered in the course
- Aptitude to apply the theoretical foundations of remote sensing to case studies
- Skills to present / communicate the scientific work developed (project), discussing the main concepts, technical solutions adopted and interpretation of the results with appropriate scientific basis and technical language

Final examination

Course	Data / methods
Imaging	Satellite, airborne, drone multispectral/hyperspectral images analysis
Imaging + Signal	Satellite, airborne, drone multispectral/hyperspectral images analysis, maybe combined with RT models (ie prosail etc…)
Signal	Analysis on spectra generated from RT models

Final examination

Project - where to start thinking?

- Further exploration of activities conducted in class and during laboratory sessions with deeper analysis or alternative methods
  - Es. Retrieve LAI and LCC with NN or GPR on a different data set
- Referring published scientific articles as examples and reproducing the work, also considering methodological variations.
  - Remote Sensing of Environment Journal (RSE) link
  - Remote Sensing Journal link
  - Transaction and Geoscience in Remote Sensing IEEE
- Online hands-on, repositories and challenges
  - https://github.com/ESA-PhiLab
  - https://github.com/ESA-PhiLab/hypernet
  - https://github.com/ESA-PhiLab/WorldCrops
  - https://github.com/ESA-PhiLab/Major-TOM

Final examination – Imaging

Project – few ideas

Satellite, airborne, drone multispectral/hyperspectral images analysis

1. Retrieval of biophysical variables (LAI, LCC, FC) with ML/DL approaches (alternative to those addressed in the lab)
2. Emulating RT models (prosail, SCOPE, 6S etc…) → reproducing the behavior of physically based RT models with ML/DL methods
3. Spikes analysis of indoor hyperspectral images
4. Land use land cover semantic segmentation map i.e., vegetation species detection
5. Clouds mask for airborne images or satellites
6. ….
7. ….

Final examination – Signal

Project – few examples

1. Emulating RT models (prosail, SCOPE, 6S etc…) → reproducing the behavior of physically based RT models with ML/DL methods

2. Hybrid retrievals RT models + ML/DL retrieval algorithms

3. Time series analysis of spectral data (i.e., field spectroscopy with ground based spectrometers)

Thesis Proposals

Potential Thesis

Retrieval of Solar-Induced Fluorescence (SIF) with ML/DL algorithms in the framework of the European Space Agency (ESA) FLuorescence EXplorer (FLEX) mission

The FLEX mission will map vegetation solar-induced fluorescence (SIF) to provide the most innovative and unique set of measurements to increase our understanding of actual photosynthetic efficiency, and the status of vegetation health. This information is crucial for advancing knowledge of the global carbon cycle, improving agricultural management, and ensuring food security. Satellite launch currently planned for mid 2026 (maybe 2027?).

ML/AI algorithms represent a promising approach to further develop the currently available retrieval algorithms to process field spectrometers, airborne and satellite data and develop novel applications.

Tutor: Prof. Sergio COGLIATI

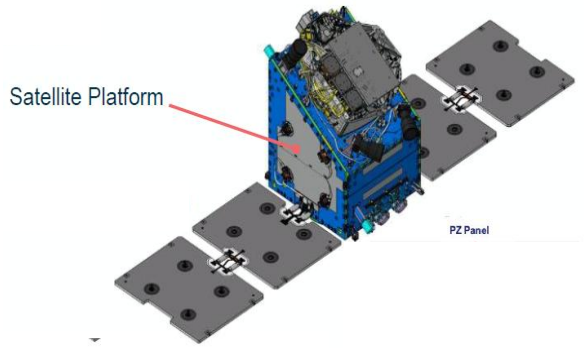
Hybrid in person / remote; possibility for field-airborne campaigns summer 2025

Topics:

- Imaging spectroscopy (ultra-spectral)
- Retrieval algorithms
- Radiative Transfer modeling of vegetation and atmosphere
- Satellite simulations / airborne images / field or drone spectrometers

Related Projects ongoing at UNIMIB:

- ESA FLEX-Data Innovation Science Cluster (satellite)
- ASI FLEX-In-land Terrestrial Airborne (airborne)
- ESA Fiducial Reference Measurements 4 FLUO (FRM4FLUO) (field spectrometer)



Links

https://www.esa.int/Applications/Observing_the_Earth/FutureEO/FLEX

https://earth.esa.int/eogateway/missions/flex#instruments-section

https://www.magellium.com/en/projet/flex-l2-et-flex-disc/

https://doi.org/10.1016/j.rse.2019.04.030

Potential Thesis

DL/ML algorithms for vegetation diseases identification and mapping from UAVs for agricultural applications

To establish an innovative algorithms for diagnosing plant diseases and monitoring vegetation responses to pathogens through the integration of hyperspectral imaging, Solar-Induced Fluorescence (SIF), and thermal-infrared (TIR) and LiDAR data. Field experiments are conducted to advance RS methodologies across plots of varying cultivar susceptibility and pathogen treatments. Multiscale RS data are collected with UAV-based spectral imaging over the entire field, complemented by ground-based top-of-canopy and leaf-level field spectroscopy and SIF measurements.

Tutor: Prof.ssa Laura SIRONI (UNIMIB), Prof. Sergio COGLIATI (UNIMIB)

In person / remote / possibility for field-airborne campaigns summer 2025 in Pisa (with University of Pisa and CNR)

Topics:

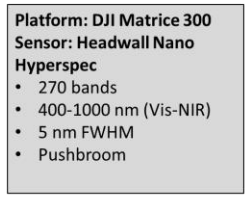
- imaging spectroscopy / thermal
- novel retrieval algorithms for very high spatial resolution from drone
- Radiative Transfer modeling of vegetation
- Drones

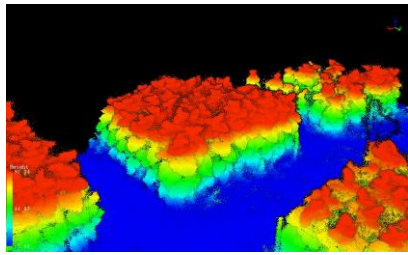
Related Projects ongoing at UNIMIB:

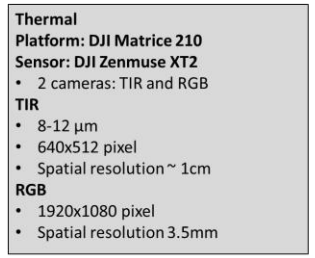
- MUSELY – Italian Ministry of University and Research

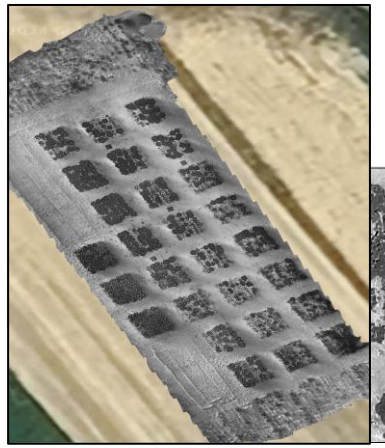
Datasets:

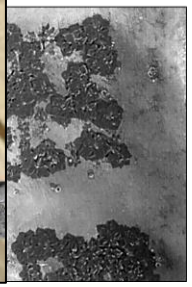
- 2024 sunflower (available)
- 2025 tomatoes (to be collected on summer 25 → possibility to participate to field survey)











Potential Thesis

1) Application of semi-empirical approaches and machine learning for modeling the **directional anisotropy of surface temperature** for future satellite missions such as LSTM, SBG-TIR, and TRISHNA;

2) Estimation of **physical parameters of snow** using hyperspectral satellite imagery from CHIME and PRISMA.

Tutor: Prof. Roberto COLOMBO (UNIMIB)

Hybrid in person / remote; possibility for field-airborne campaigns summer 2025

Topics:

- Imaging spectroscopy / thermal
- Retrieval algorithms / RT modeling
- Vegetation / snow
- Satellite / field spectrometers

Related Projects ongoing at UNIMIB:

- ASI Theresa (satellite)

Potential Thesis

Application of AI/ML for water remote sensing applications (lakes)

Different topics available to be discussed with Claudia GIARDINO and me. Please contact me and I will open the contact with Claudia

Tutor: Dr.ssa Claudia GIARDINO (CNR-IREA, Milano)

Hybrid in person / remote; possibility for field-airborne campaigns summer 2025

Topics:

- Imaging spectroscopy
- Retrieval algorithms / RT modeling
- water
- Satellite / airborne / field spectrometers

Related Projects ongoing at UNIMIB:

- ASI FLEX-ITA (airborne)
- …. (satellite)
- …..

End