UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Signal and Imaging Acquisition and Modelling in Environment

2627-1-F9103Q017

Aims

This course aims to equip students with a comprehensive understanding of advanced signal and image processing techniques tailored for environmental applications. By bridging the gap between complex remote sensing technologies –such as remote observations, hyperspectral imaging and satellite observations– and state-of-the-art Artificial Intelligence, the course prepares students to analyze high-resolution data and extract meaningful insights. Ultimately, students will develop the critical judgment, communication, and autonomous learning skills required to build, evaluate, and articulate AI-driven solutions for modern environmental challenges. Upon successful completion of this course, students will be able to:

1. Knowledge and understanding: Demonstrate an in-depth understanding of signal and image acquisition and analysis techniques relevant to environmental applications, focusing on advanced methodologies such as remote sensing, hyperspectral imaging, and satellite or telescope-based observation systems.

2. Applying knowledge and understanding: Apply signal and image processing techniques to high-resolution data acquired through complex remote sensing systems, extracting meaningful features using state-of-the-art Machine Learning and Artificial Intelligence tools

3. Making judgments: Critically assess the quality and reliability of acquired environmental data, select appropriate AI models and processing pipelines, and interpret results in light of application-specific constraints and objectives.

4. Communication skills: Effectively communicate complex signal and image analysis processes and their results through technical reports, visual presentations, and interdisciplinary collaboration, utilizing precise terminology and advanced data visualization tools.

5. Learning skills: Autonomously adapt to the rapidly evolving fields of environmental sensing, imaging technologies, and AI-based data analysis, demonstrating the ability to keep pace with emerging tools, methodologies, and scientific literature.

Contents

Basic theory of signal and imaging detectors, statistics and signal to noise ratio optimization, identification of sources and signals in noisy data. Analysis of time series and imaging data with ML methods (e.g. random forest classifier/regressors, self organizing maps, deep learning methods) using Python. Forecasts and tests of ML predictions.

Detailed program

- Operation and characterization of imaging detectors (focusing on optical CCDs), description of the calibrations needed.
- Characterization and description of other detectors for remote sensing of the environment.
- Statistics of photon counting experiments, noise and background sources, techniques for the detection of signals above the noise.
- Data handling packages in Python language, brief description of data visualization methods and ML implementations.
- Hands-on projects will be proposed where the students will learn how to extract relevant data and images from multi-petabyte catalogs and how to analyze them.
- Acquire imaging data from Bicocca Telescope and use ML with the aim to identify and characterize sources in the sky and the effects of light pollution.

Prerequisites

Classes of the first semester

Teaching form

Lectures followed by hands-on sessions. The students will use their laptop in the classroom. Coding and analysis platforms will be accessible through the GMail account of the Bicocca campus (Google Colab).
All activities will be in English.

Textbook and teaching resource

Relevant material will be provided via handouts.

Semester

Second semester.

Assessment method

Written individual scientific report on the activities performed in the lab and oral exam on the topics presented in the lab and discussed during the lessons.

Office hours

By appointment (via email).

Sustainable Development Goals