E-TRAINEE: OPEN E-LEARNING COURSE ON TIME SERIES ANALYSIS IN REMOTE SENSING

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BACKGROUND & OBJECTIVE

Open access to archives of Earth Observation missions, periodically acquired nation-wide aerial imagery and LiDAR point clouds, and various research datasets, together with open tools for **Remote Sensing Time Series** (RSTS) data processing, have brought new possibilities in RS research but also challenges in education. The topic of RSTS **analysis** has become an essential part of MSc curricula in geoinformatics, geography, and related fields. Open learning materials systematically addressing this issue at the master's level are rare, and their development is time and resource demanding. Thus, based on previous collaboration within the 4EU+ University Alliance, the research groups from Charles University, Heidelberg University, University of Innsbruck, and University of Warsaw joint their specific expertise and developed an **open E-learning course on Time Series Analysis in RS for Understanding Human-Environment Interactions (E-TRAINEE)**. The course consists of four Modules covering the topics of TS from general approaches (M1) to specific methods of processing TS of satellite multispectral images (M2), 3D/4D point clouds (M3), and aerial image and laboratory spectroscopy (M4). Theoretical parts are supported with exercises/tutorials and case studies based on research activities of the involved teams. The course is accessible via a web site and is **published under the CC-BY SA 4.0 license, and the** associated **code is under the MIT license**. The primary target groups are **MSc and PhD students of geoinformatics and geography,** but it is also relevant to students of **environmental studies, ecology, or geology**, as well as **potential users from the public and private sectors** dealing with applications of RS.

COURSE STRUCTURE AND CONTENT

Prerequisites

Required basic knowledge in RS, statistics, and programming; links to available external online learning materials are provided.

Module 1: Methods of Time Series Analysis in Remote Sensing

Module 2: Satellite Multispectral Images Time Series Analysis

Module 3: 3D/4D Geographic Point Cloud Time Series Analysis

Module 4: Airborne Imaging and Laboratory Spectroscopy Time Series Analysis

Each "**Module**" contains several "**Themes**" (T) divided into a i) **theoretical section** supported with a list of references for further reading are concluded with self-evaluation quizzes, ii) **exercises/tutorials** with an indication if they are compulsory or optional. The practical exercises are based on open software tools/platforms such as QGIS, CloudCompare, EnMAP-Box, Google Earth Engine, or scripting in Python or R. Modules 2 – 4 include "**Case Studies**" (CS) with a deeper look into selected research problems.

Software

A list of used **software** including installation instructions and tutorials.

Use Cases and Data

Description and links to the course datasets, i.e., existing open archives (e.g., Copernicus, Landsat) or **data** collected within the research projects of the involved institutions (e.g., LiDAR point clouds, RPAS hyperspectral images, spectroradiometer measurements) released under a CC-BY SA license.

Module 1

(T1) Principles of remote sensing time series

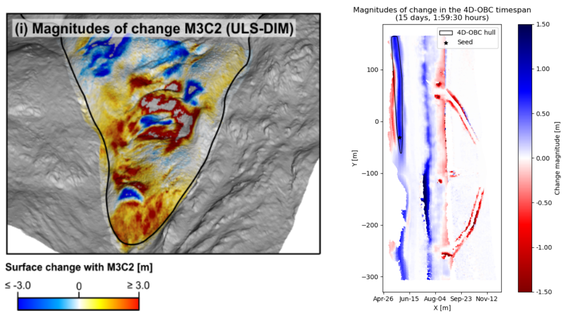
(T2) Large time series datasets in remote sensing

(T3) Time series analysis based on classification

(T4) Trajectory-based analysis

(T5) Spatio-temporal data fusion

(T6) Reference data, validation and accuracy assessment



Module 3: Rock glacier changes and beach monitoring based on LiDAR 3D/4D point clouds.

Module 3

(T1) Principles of 3D/4D geographic point clouds

(T2) Programming for point cloud analysis with Python

(T3) Principles and basic algorithms of 3D change detection and analysis

(T4) Time series analysis of 3D point clouds

(T5) Machine learning-based 3D/4D point cloud analysis

(CS 1) Multitemporal 3D change analysis at an active rock glacier

(CS 2) Time series-based change analysis of sandy beach dynamics

Module 2

(T1) Principles of multispectral imaging

(T2) Temporal information in satellite data

(T3) Image processing workflow

(T4) Multitemporal classification

(T5) Vegetation change and disturbance detection

(CS 1) Monitoring tundra grasslands in Krkonoše/Karkonosze Mountains

(CS 2) Effects of pollution in Ore Mountains

(CS 3) Forest disturbance detection in Tatra Mountains

Module 4

(T1) Principles of imaging and laboratory spectroscopy

(T2) Aerial/RPAS hyperspectral data acquisition and pre-processing

(T3) In-situ and laboratory spectroscopy of vegetation

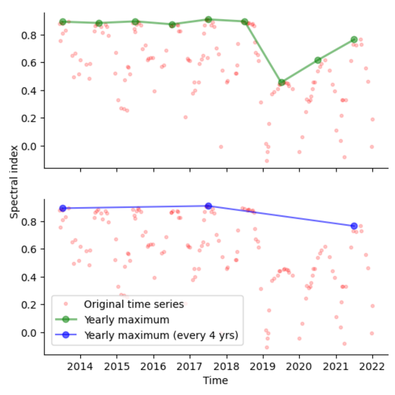
(T4) Machine learning in imaging spectroscopy

(T5) Temporal vs. spatial and spectral resolution

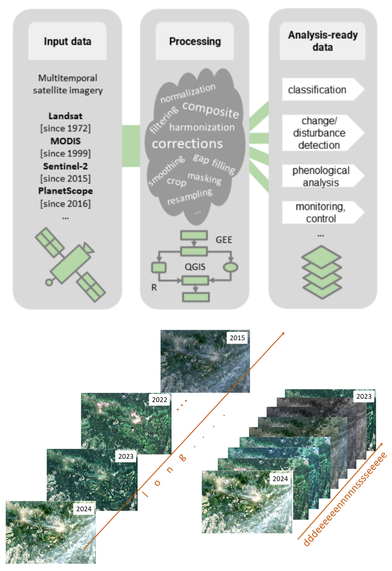
(CS 1) Seasonal spectral separability of selected grass species of the Krkonoše Mountains tundra ecosystem

(CS 2) Discrimination of selected grass species from time series of RPAS hyperspectral imagery

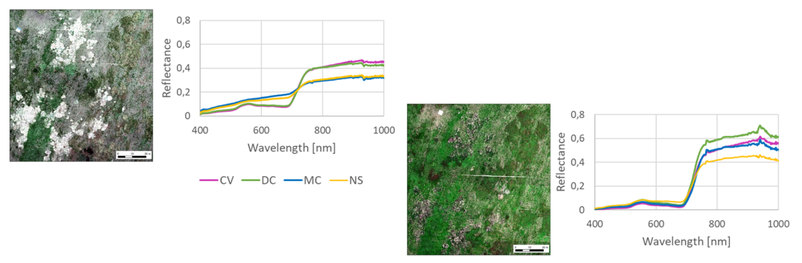
(CS 3) Seasonal dynamics of flood-plain forest



Module 1: Example of a spectral trajectory. The yearly maxima of a vegetation index indicate a land surface change in 2019 (top), whereas this is not well visible in a coarser time series (bottom), illustrating how the detectability of changes depends on the temporal resolution of original or aggregated data.



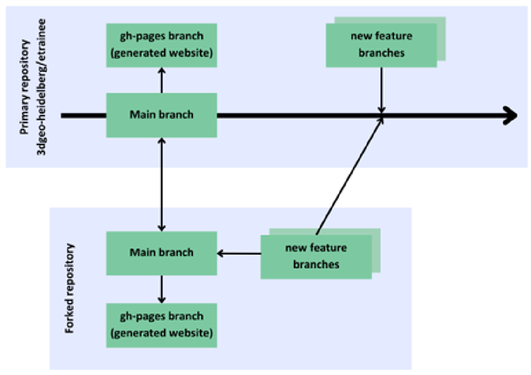
Module 2: Overview – from input data to analysis-ready data (top) and long and dense time series data examples (bottom) (source of Sentinel-2 image: ESA).



Module 4: Spectral signatures of selected grass species derived from Nano-Hyperspec® imagery collected in the Krkonoše Mts. tundra (50.7308N, 15.6889E) in June (left) and July (right) 2020. CV – *Calamagrostis villosa*, DC – *Deschampsia cespitosa*, MC – *Molinia caerulea*, NS – *Nardus stricta*.

COURSE IMPLEMENTATION

The course website is generated automatically from a GitHub repository. The content is stored in markdown (.md) and Jupyter (.ipynb) files. To limit the repository size, large datasets are presented on Zenodo, and videos are uploaded on YouTube. The functionality has been extended with JavaScript for quizzes at the end of lessons. There is potential in actively using GitHub Issues to gather student feedback. The repository includes templates that make it simple to build new modules.



E-TRAINEE GitHub branch structure: Forking creates a stable version of the website, which is independent of potential changes in the main branch. This system also makes it simple to improve the course when teaching it. Any potential changes can be easily transferred back into the main repository without worrying about disrupting anyone else who may be teaching the course at the same time.

CONCLUSION

The international collaboration resulted in the development of comprehensive, open, and research-oriented learning materials beyond the curricula of geography and geoinformatics at many universities. It is based on a multidisciplinary approach. Its focus is on improving and increasing digital literacy of participants, i.e., understanding algorithms of data processing, programming, and automatic analysis of large geographic datasets. The course benefits from the research projects of the four involved universities and thus is an example of knowledge transfer from research to research-oriented education.

Carrying out a transnational project has brought much more than an opportunity to create broad course content. The main benefits include:

- sharing knowledge, skills, and best teaching practices,
- saving time and resources for learning material development,
- having a base for collaborative online teaching and follow-up activities such as summer schools,
- stimulating new ideas for further collaboration in education and research,
- initiating student mobility among partner universities.

Starting from the academic year 2023/24, the course will be implemented in the MSc curricula in geography and geoinformatics of the involved universities in different forms. The course materials will be continuously updated, and new releases will be made available for public use. Its design allows for an easy extension of new modules, themes, or case studies.

ACKNOWLEDGEMENTS

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