Deliverable No. D2.2
“Course plans for 4 courses”

Lead Beneficiary – LU

Type – R

Dissemination level – PU

Due Date – M9

Course Syllabus

Course title: Geospatial Intelligence

Course ECTS credits: 10

Course hour distribution:

Theory	Lab-Supervised	Lab-Unsupervised	Seminar	Total
35	60	125	30	250

Annotation of the course:

Students will explore theory and practice of the application of artificial intelligence (AI) to process geospatial data. The course involves an introductory cycle of lectures on classical geostatistics; then, optimization and machine learning applied to geospatial data are discussed. Learning is moved from a lecture centred approach to a practical centred one: there, a significant number of hours are devoted to individual work that is implemented at different levels: lab-work, where short exercises have to be solved; projects, in which longer individual tasks are assigned that include implementation of libraries. In lab work and projects, clearly students will be supported by tutors. Finally, seminars are planned, in which individual topics are assigned to students, who are required to prepare a presentation. In such a way, not only knowledge but also practical and evaluation competences can be achieved.

Aim of the course:

To learn theory and practice, up to the level of libraries implementing, of artificial intelligence applied to the processing (data preparation, classification, interpolation) of geospatial data.

Topics:

A. Introduction
   1. General introductions on AI and Geospatial Applications
   2. Fundamentals of statistics and matrix algebra
   3. Data Preparation and exploration
   4. Classification and clustering: supervised and unsupervised approaches (general concepts)
   5. Spatial interpolation and regression: from polynomial to kriging

B. Optimization and Machine learning
   1. Single Objective Optimization (GA)
   2. Multi-Objective Evolutionary Optimization (NSGA-II)

3. Classification (SVM and Decision Tree) 4. Artificial Neural network (ANN) 5. Deep Learning 6. Ensemble Learning and hyper parameter tuning 7. Geographic Weighted Machine Learning

Learning outcomes:

1	Knowledge and understanding	- To understand and explain the classical methods statistical processing, classification and interpolation - To understand and explain the optimization methods and machine learning approaches listed in the topic - To understand and explain the application of AI to geospatial data and problems
2	Competences and skills	- To use and apply AI software and libraries for geospatial data processing - To design and develop functions for geospatial data processing by optimization and machine learning
3	Judgements and evaluations	- In processing of geospatial data, to decide algorithms and parameters suitable for processed data - In the analysis of the results, to assess their accuracy, to a posteriori evaluate the correctness of the applied methods

Methods of course studies:

The students will be monitored and evaluated in progress while they will work on and discuss exercises. The course has a written exam. Students will prepare seminar and final project reports. They comment on each others' seminars.

Methods for assessment:

	Description	**Dublin Descriptors**
Written exam	To evaluate knowledge and understanding of students on theoretical aspects of Geospatial Intelligence	1
Assessment of laboratory	To evaluate the competences, skills and evaluation capabilities in Geospatial Intelligence applications	2,3
Seminar	To evaluate knowledge and understanding in GI	1,3

	researches	

Prerequisites:

- General knowledge of standard statistics: 5 ECTS
- General knowledge of remote sensing / earth observation: 5 ECTS
- General knowledge of GIS: 5 ECTS
- General skill in programming: 5 ECTS

Tentative schedule:

Week	Type (T-TR-L)*	Topic	Note
W1	T	General introductions on AI and Geospatial Applications	2h
W1	T	Fundamentals of statistics and matrix algebra	5h
W1	LS	Exercises on Statistics and matrix	3h
W1	LI	Training of Statistics and matrix	7h
W1	T	Data Preparation and exploration	4h
W1	LS	Exercises on Data preparation and exploration	4h
W1	LI	Training of Data preparation and exploration	6h
W1	T	Classification and clustering: supervised and unsupervised approaches (general concepts)	5h
W1-2	T	Spatial interpolation and regression: from polynomial to kriging	4h
W2	LS	Exercises on Classification and interpolation	3h
W2	LI	Training of Classification and interpolation	7h
W2	T	Single Objective Optimization (Genetic Algorithms)	2h
W2	LS	Exercises on Genetic algorithms	5h
W2	LI	Training of Genetic algorithms	10h
W2	T	Multi-Objective Evolutionary Optimization (NSGA-II)	2h

W2	LS	Exercises on Multi-Objective Evolutionary Optimization	8h
W3	LI	Training of Multi-Objective Evolutionary Optimization	16h
W3	T	Classification (SVM and Decision Tree)	3h
W3	LS	Exercises on SVM	5h
W3	LI	Training of SVM	11h
W3	LS	Exercises on Decision Tree	5h
W4	LI	Training of Decision Tree	11h
W4	T	Artificial Neural Networks	2h
W4	LS	Exercises on Artificial Neural Networks	6h
W4	LI	Training on Artificial Neural Networks	14h
W4	T	Deep Learning	2h
W4-5	LS	Exercises on Deep Learning	8h
W5	LI	Training of Deep Learning	16h
W5	T	Ensemble Learning and hyper parameter tuning	2h
W5	LS	Exercises on RF and hyper parameter tuning	8h
W5-6	LI	Training of RF and hyper parameter tuning	16h
W6	T	Geographic Weighted Machine Learning	2h
W6	LS	Exercises on GWML	5h
W6	LI	Training of GWML	11h
W6-7	S	Seminar: preparation	25h
W7	S	Seminar: discussion	5h

**T = Theory, LS = Lab-supervised, LI = Lab-individual study, S = Seminar, P = Project.*

Bibliography:

No.	Publication authors, year of issue, name, place of issue, publisher, (address of electronic publications and website)
1	Aurelien Geron, 2019, Hands-on Machine Learning with Scikit-Learn, Keras & TensorFlow - Concepts, Tools, and Techniques to Build Intelligent Systems, O'Reilly Media, Incorporated
2	Ke-Lin Du, M. N. S. Swamy, 2016, Search and Optimization by Metaheuristics - Techniques and Algorithms Inspired by Nature, Springer International Publishing Switzerland
3	Bradley Efron, Trevor Hastie, 2016 Computer Age Statistical Inference, Algorithms, Evidence, and Data Science, Cambridge University Press
4	Sebastian Raschka, Vahid Mirjalili, 2019, Python Machine Learning : machine learning and deep learning with Python, Scikit-learn, and TensorFlow 2, Packt publishing, Birmingham
5	Alain Pétrowski, Sana Ben-Hamida, 2017, Evolutionary Algorithms, Wiley online Library, https://onlinelibrary.wiley.com/doi/book/10.1002/9781119136378
6	Google Earth Engine API documentation online, https://developers.google.com/earth-engine/
7	Google Earth Engine API documentation – Machine Learning in Earth Engine online, https://developers.google.com/earth-engine/guides/machine-learning
8	Google Earth Engine Educational resources online, https://developers.google.com/earth-engine/edu

Required IT resources:

No.	Software name	License
1	Scikit-learn	Open Source
2	Python Anaconda and Jupyter	Open Source
3	QGIS	Open Source
4	Google Earth Engine	Google (free to use for students)
5	SNAP	ESA (free to use for students)

6	other libraries (e.g., https://geodacenter.github.io/)	Open Source

Course completed by Nguyen Quang Minh and Ludovico Biagi

Project coordinator Maria Antonia Brovelli

Course Syllabus

Course title: Earth Observation

Course ECTS credits: 10

Course hour distribution:

Theory	Lab-supervised	Lab-unsupervised	Seminar	Total
33	70	100	47	250

Annotation of the course:

This course introduces different techniques that are commonly used in observing the Earth. using satellite data registrations. The course starts with introducing basic knowledge and theories about electromagnetic radiation and atmospheric properties, different sensors (radar + passive) and multi-spectral imageries. The second module provides knowledge and skills in digital image processing techniques including techniques to classify images based on different algorithms. The third and last module provides different applications using satellite data e.g. hot-spot mapping, working with vegetation indices, time series of satellite data working with time series of data to map changes, mapping fire events etc.

Aim of the course:

To get knowledge, understanding and practical skills of different remote sensing data and techniques to map and monitor the Earth.

Topics:

A. Basic knowledge and theories
1) EM radiation and atmospheric properties
2) Different satellite systems and platform
3) Introduction to multi-spectral imageries
4) Introduction to Radar theories (SAR and InSAR)

B. Digital Image processing
5) Pre-processing techniques
6) Image enhancement
7) Image classification techniques

C. Applications
8) Visual image interpretation
9) Vegetation indices and time series analysis

10) Hot-spot identification
11) Mapping natural hazardous events
12) Mapping of fire events
13) SAR and InSAR applications: Topographic and 3D objects

Learning outcomes:

1	Knowledge and understanding	- Understanding multispectral images, spectral and time resolutions. - Understanding critical pre-processing and enhancement techniques, and different classification techniques. - Knowledge of synthetic aperture radar, understanding the frequencies used in receiving radar signals. - Knowledge of some common application techniques to map and identify natural hazards such as: soil erosion, landslide etc. - Knowledge of some common applications of SAR and InSAR in terrain and 3D object mapping.
2	Competences and skills	- Skills in working with digital RS images and classification techniques. - General skills in working with Radar images. - Competence in interpreting vegetation indices - Ability to identify different land surface features and processes using medium-high resolution satellite imagery.
3	Judgements and evaluations	- Critical understanding of how the atmosphere affects and impacts satellite sensor measurements and EO images. - Judgement about limitations and advantages of mapping and classification techniques. - Critical judgement of precision of geodata i.e. raster cell sizes and polygon boundaries.

Methods of course studies:

The students will be monitored and evaluated in their progress while they will work on and discuss exercises. The course has a written exam. Students will prepare seminar and final project reports. They comment on each others' seminars.

Methods for assessment:

	Description	**Dublin Descriptors**

Written exam	Theoretical examination of the theoretical lecture parts	1, 3
Projects	Practical exercises and projects are a major part of the course. On all projects a pass is required. The exercises or small projects will be reported either as a scientific report or as an oral presentation at seminars.	1, 2, 3
Seminar	Presentation and seminars of the practical projects	1, 2, 3

Prerequisites:

- General knowledge of GIS equal to 5 ECTS

Tentative schedule:

Date	Type (T-Tr-L)*	Topic	Note
W1	T	EM radiation and atmospheric properties	2h
W1	T	Different satellite sensors and platforms	2h
W1	S	Different satellite sensors and platforms	3h
W1	T	Introduction to multi-spectral imageries	2h
W1	T	Introduction to Radar theories (SAR and InSAR)	4h
W1	T, LS, LI, S	Pre-processing images	25h
W2	T, LS, LI, S	Image enhancement	25h
W2	T, LS, LI, S	Unsupervised and Supervised classification techniques	25h
W3	T, LS, LI, S	Object oriented classification techniques	25h
W3	T, LS, LI, S	Visual image interpretation	25h
W4	T, LS, LI, S	Vegetation indices and time series analysis	24h
W4	T, LS, LI, S	Hot-spot identification	22h
W5	T, LS, LI, S	Mapping natural hazardous events	22h

W5	T, LS, LI, S	Mapping fire events	22h
W6	T, LS, LI, S	SAR and InSAR applications: Topographic and 3D objects	22h

**T = Theory, LS = Lab-supervised, LI = Lab-individual study, S = Seminar*

Bibliography:

No.	Publication authors, year of issue, name, place of issue, publisher, (address of electronic publications and website)
1	Floyd F. Sabins, James M.Ellis (2020). Remote Sensing: Principles, Interpretation, and Applications, 4th Edition. ISBN: 978-1-4786-3710-3. Waveland Press.
2	Paolo Tarolli, Simon M. Mud (Volume Editors) (2020). Remote Sensing of Geomorphology Vol 23 in Developments in Earth Surface Processes (J.F. Shrode, Series Editors). ISBN: 978-0-444-64177-9. Elsevier.
3	Morton John Canty (2019), Image Analysis, Classification and Change Detection in Remote Sensing with Algorithms for Python (Fourth Edition). ISBN: 978-1-138-61322-5. CRC Press
4	Pinliang Dong, Qi Chen (2018). LiDAR Remote Sensing and Applications in Remote Sensing Applications (Qihao Weng, Series Editors). ISBN: 978-1-138-74724-1. CRC Press
5	Chandra P. Giri (2012). Remote Sensing of Land Use and Land Cover: Principles and Applications in Remote Sensing Applications (Qihao Weng, Series Editors). ISBN: 978-1-4200-7074-3. CRC Press
6	John R. Jensen (2015). Introductory Digital Image Processing: A Remote Sensing Perspective, 4th Edition. ISBN: 978-0-134-05816-0. Pearson

Required IT resources:

No.	Software name	License
1	QGIS	Open Source
2	Google Earth Engine	Google (free to use for students)
3	SNAP	ESA (free to use for students)
4	R studio	Open Source

Course completed by Pham Gia Tung and Micael Runnstrom

Project coordinator Maria Antonia Brovelli

Course Syllabus

Course Title: Digital Twin Earth

Course ECTS credits: 5

Course hour distribution:

Lecture	Lab-Supervised	Lab-Unsupervised	Seminar	Project	Total
18	20	42	15	30	125

Annotation of the course:

Students will be introduced to both theoretical foundations and digital ecosystems required for the application of the Digital Twin(s) of the Earth and their added value in the next-generation monitoring and forecasting operations of natural and human activities. The course will equip students with knowledge and skills on Digital Twins theories and technological frameworks and will enable them to make use of Digital Twins for a wide range of applications, including but not limited to Climate Change Adaptation, Environmental Analysis and Urban Development, and for practical decision-making support in relevant fields. The course is designed with practical examples in the EU countries, Vietnam and beyond.

Aim of the course:

To acquire consciousness and technical skills of digital twins and their applications in Climate Change, Urban Development and Environmental sciences, based on the most recent conceptual frameworks, practical examples and available supporting software solutions.

Topics:

1. Digital Twin concepts, transformative challenges, relevant ethics, and development trends
2. Digital Twin Earth application (e.g. climate, atmosphere and air quality, smart cities, disaster response, urban planning)
3. Digital Twin Earth theoretical framework (definitions, purposes, Model Based System Specifications, interoperability)
4. Digital Twin Earth enabling technologies (such as Big Data & IoT; SDIs; APIs, cloud computing, GIS, satellites, geoprocessing, data cubes, point clouds, available supporting software and data platforms)
5. Digital Twin Earth application components (data archives, viewers, nowcast and forecast units, what/if simulators, decision-support systems)
6. Digital Twin Earth practical examples (urban digital twins, digital Earth regional and

national development, etc.) 7. Digital Twin Earth development lab (domain-specific Digital Twin Earth application based on WebGIS and scientific programming technologies)

Learning outcomes:

1	Knowledge and understanding	- To understand Digital Twin concepts and its application - To understand and explain digital twin models specifications - To identify requirements for digital twin applications
2	Competences and skills	- To design basic digital twin applications based on requirements - To develop digital twin prototype applications based on free and open-source software tools - To enhance critical spatial thinking, problem-solving, teamwork and communication skills
3	Judgements and evaluations	- To decide on proper development patterns for digital twin applications - To evaluate and test digital twin applications against requirements

Methods of course studies:

The progress of the students will be monitored during their work on exercises and seminar preparation. The course has an intermediate seminar, a final project, and two final exams: written and practical exams.

Methods for assessment:

Method	Description	Dublin Descriptors
Practical exam	To evaluate competence and skills of students in using Digital Twin Earth enabling technologies	2
Seminar	To evaluate knowledge and understanding of existing Digital Twin Earth projects or application	1,3
Project	To evaluate the overall knowledge, skills and evaluation competencies of students for developing a Digital Twin Earth application	1,2,3

Written exam	To evaluate the knowledge and understanding of students on theoretical aspects of Digital Twin Earth	1

Prerequisites:

- General knowledge of GIS equal to 5 ECTS
- General knowledge and skill of WebGIS equal to 5 ECTS
- General knowledge of Earth Observation equal to 5 ECTS

Tentative schedule:

Week	Type (T-TR-L)*	Topic	Note
W1	T	Digital twining concepts, transformative challenges, ethics, and future trends	4h
W1	T	Digital Twin Earth theoretical framework and application components	4h
W1	T	Digital Twin Earth enabling technologies	8h
W1	LS/LI	Digital Twin Earth enabling technologies	20h
W2	LS/LI	Digital Twin Earth enabling technologies	42h
W3	T	Fields for Digital Twin Earth application	2h
W3	LS/LI	Digital Twin Earth practical examples	2h
W3	LS/LI	Digital Twin Earth application design	10h
W3	S	Seminar: set-up, guidance and class discussion	4h
W3	S	Seminar: preparation	11h
W3	LS/LI	Digital Twin Earth application development	10h
W3	LS/LI	Digital Twin Earth application development	10h
W4	P	Project on Digital Twin Earth application development: set-up and	8h

		guidance	
W4	P	Project on Digital Twin Earth application development: implementation	22h

**T = Theory, LS = Lab-supervised, LI = Lab-individual study, S = Seminar, P = Project.*

Bibliography:

No.	Publication authors, year of issue, name, place of issue, publisher, (address of electronic publications and website)
1	Guo, H., Goodchild, M. F., & Annoni, A. (2020). *Manual of Digital Earth* (p. 852). Springer Nature. PDF
2	Nativi, S., Mazzetti, P., & Craglia, M. (2021). Digital ecosystems for developing digital twins of the earth: The destination earth case. *Remote Sensing*, *13*(11), 2119. PDF
3	Air Force Institute of Technology (2022). Human Digital Twin and Modeling Guidebook, Technical report. PDF

Required IT resources:

No.	Software name	License
1	HTML and JavaScript (available on standard browsers)	Free and Open Source
2	Text editor such as notepad++	Free and Open Source
3	Python - Jupyter	Free and Open Source
4	Postgres-PostGIS	Free and Open Source
5	GeoServer	Free and Open Source
6	OpenLayers and Leaflet	Free and Open Source
7	Google Earth Engine	Free

Course completed by Son Pham Thai and Daniele Oxoli

Project coordinator Maria Antonia Brovelli

Course Syllabus

Course title: Geospatial Web Applications

Course ECTS credits: 5

Course hour distribution:

Lecture	Lab-Supervised	Lab-Unsupervised	Seminar	Project	Total
12	12	66	10	25	125

Annotation of the course:

Students will explore theoretical and practical concepts of geospatial web services. From a theoretical perspective they study architecture of Web GIS/Web mapping systems, markup languages (e.g. HTML, XML and GML), a scripting language, spatial web services and OGC standards. The theoretical part does also include a seminar on legal and ethical issues on Web GIS. From a practical perspective, they will learn to develop geospatial web applications including static and interactive web mapping systems. They also learn some famous open source software and libraries for developing a Web GIS.

Aim of the course:

To learn technical aspects of Geospatial Web Applications, based on the recent international standards and specifications.

Topics:

1. Dynamic HTML for rendering and interaction with maps on Web browsers.
2. Open Geospatial Consortium (OGC) standards and specifications for creating Geospatial Web Services, with special focus on Web Map Service (WMS) interface standard and GML/KML encoding standard.
3. Open source tools for creating Geospatial Web Applications.

Learning outcomes:

1	Knowledge and understanding	- To describe Web GIS architecture - To understand and explain OGC standards and specifications - To define and explain distributed geospatial web services

2	Competences and skills	- To develop interactive web mapping system - To use open source web mapping tools (client and server side)
3	Judgements and evaluations	- To decide proper OGC standards for a developing a Geospatial Web Application - To evaluate a Geospatial Web Applications

Methods of course studies:

The progress of the students will be monitored and evaluated while they work on and submit exercises. The course has a midterm exam and two final exams: a written exam and a practical exam. It also has a seminar and a final project.

Methods for assessment:

	Description	Dublin Descriptors
Mid-term exam	To evaluate knowledge and understanding of students on theoretical aspects of Geospatial Web Applications, in the midway of the course.	1
Written exam	To evaluate knowledge and understanding of students on theoretical aspects of Geospatial Web Applications	1
Practical exam	To evaluate competence and skills of students as well as judgement and evaluation for developing a Geospatial Web Applications	2, 3
Assessment of laboratory artefacts	To evaluate technical skills and competences linked to the theoretical knowledge	1,2
Seminar	To evaluate knowledge and understanding on legal aspects of publishing maps on internet	1,3
Project	To evaluate overall knowledge, skills and evaluation competences of students for developing a Geospatial Web Application	1,2,3

Prerequisites:

- General knowledge of GIS equal to 5 ECTS
- General knowledge and skill of programming equal to 5 ECTS

Tentative schedule:

Week	Type (T-P-L)*	Topic	Note
W1	T	Web GIS and Web Mapping Techniques	2h
W1	T	HTML	2h
W1	LS/LI	Web Map User Interface, using HTML	10h
W1	T	JavaScript	2h
W1	LS/LI	Static Map Publishing, using HTML and JavaScript	10h
W2	T	OGC Standards and Specifications	2h
W2	LS/LI	Setup Geoserver and OpenLayers	6h
W2	LS/LI	Static Web Mapping	20h
W2	T	XML, GML and KML	4h
W2	LS/LI	KML	12h
W3	S	Seminar on legal aspects of map publishing	10h
W3	LS/LI	Interactive Web Mapping, using OpenLayers and Geoserver	20h
W4	P	Project on developing a Geospatial Web Application	25h

**T = Theory, LS = Lab-supervised, LI = Lab-individual study, S = Seminar, P = Project.*

Bibliography:

No.	Publication authors, year of issue, name, place of issue, publisher, (address of electronic publications and website)
1	Stefanakis, E. (2015). An introduction to web mapping & geospatial web services, CreateSpace Independent Publishing Platform, 157p.
2	Stefano Iacovella (2017). GeoServer Beginner's Guide (second edition)
3	Thomas Gratier (2014). Openlayers 3 Beginner's Guide (http://openlayersbook.github.io/)

Required IT resources:

No.	Software name	License
1	HTML and JavaScript (available on standard browsers)	Open Source
2	Text editor such as notepad++	Open Source
3	OpenLayers	Open Source
4	Geoserver	Open Source

Course completed by Thanh Trinh and Ali Mansourian

Project coordinator Maria Antonia Brovelli