Course guide
230743 - AI4EO - Ai and Big Data for Earth Observation

Last modified: 13/06/2024

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 739 - TSC - Department of Signal Theory and Communications.

Degree: MASTER'S DEGREE IN TELECOMMUNICATIONS ENGINEERING (Syllabus 2013). (Optional subject).
MASTER'S DEGREE IN ADVANCED TELECOMMUNICATION TECHNOLOGIES (Syllabus 2019). (Optional subject).

Academic year: 2024 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: Consultar aquí / See here:
https://telecos.upc.edu/ca/curs-actual/coordinadors-i-professorat

Others: Consultar aquí / See here:
https://telecos.upc.edu/ca/curs-actual/coordinadors-i-professorat

PRIOR SKILLS

This subject explores the transformative impact of artificial intelligence (AI) and big data technologies on the field of Remote Sensing (RS) for Earth observation (EO). Through this course, you will delve into the methods and applications of AI in processing and analyzing large datasets obtained from various RS technologies. By the end of this course, you will have a comprehensive understanding of how these cutting-edge tools can be used to monitor and analyze our planet in unprecedented detail.

In order to get the most out of this important and rapidly evolving field, here are the recommended prior skills:
• Basics of Electromagnetism: They are fundamental to the technologies and methods used in EO. A solid grasp of electromagnetic waves, their propagation, and interaction with different media will enhance your comprehension of how data is collected and interpreted from various sensors.
• Basics of Signal/Data/Image Processing: Familiarity with the basics of signal processing is important. This includes understanding how to filter, analyze, and interpret signals. These skills will help you manipulate and extract meaningful information from raw data, which is a cornerstone of big data analytics. Skills in image processing will be relevant, as much of EO relies on visual data captured from satellites and other RS technologies.
• Coding: Familiarity with coding is desirable as the lab sessions and the project may involve it.

Whether you have experience in signal/data processing or image processing, these aptitudes will provide a strong foundation to build upon. With these skills, you'll be well-equipped to tackle the challenges and opportunities presented in the field of AI and Big Data for EO. Your ability to integrate and apply these principles will not only enhance your understanding but also empower you to contribute meaningfully to this dynamic and impactful field.

TEACHING METHODOLOGY

Master classes and/or talks by lecturer(s)
Laboratory hands-on experiences
Project-based learning
Cooperative learning

LEARNING OBJECTIVES OF THE SUBJECT

Satellite imagery and Remote Sensing (RS) for Earth Observation (EO) are used to acquire information about the Earth's surface and to analyze its physical characteristics. These technologies allow facing global risks affecting our society: climate change, extreme weather, biodiversity loss, human environmental damage or natural resources crisis [1]. Nevertheless, processing of satellite imagery is also emerging as an important technique in sectors like precision agriculture, hydrology, infrastructures management, maritime security and insurances or health, all together with a market size valued at USD 12.40 billion in 2019 and with an expectation to grow at a compound annual growth rate (CAGR) of 11.6% from 2020 to 2027 [2].

We are in the era of Big Earth Data or RS 2.0, where the target is moving from the upstream segment focused on the launching services and the manufacturing of satellites to the mid-and downstream segments focused on data management infrastructures and data processing and exploitation. The Sentinel Data Access System of the European Union's Earth observation program Copernicus [3] holds a complete archive of almost 78 PB of data, supporting a monthly publication rate of over 1.23 million products/month with a volume of 750 TB. Since the start of operations, almost 5 billion products have been downloaded by users, with a total volume of 720 PB, by a community of more than 170.000 users. The analysis and exploitation of this vast and varied data are facing new challenges and opportunities that require the use of Artificial Intelligence tools for Big Data processing.

Motivated by these emerging needs in the private and public sectors, this subject is designed for those who would like to improve their knowledge in the field of Artificial Intelligence (AI) focusing on satellite imagery from a technical perspective and with a focus on the development and humanitarian practice, as exemplified UN's Sustainable Development Goals (SDG) [4]. Skills in AI are already obliquitous for the 21st century Engineers and Data Scientists. In this subject, you will be introduced to this field of science by covering the most popular topics and tasks in Machine Learning (ML). Examples and programming material will be provided to illustrate the ideas presented in the subject. These will be in Python using conventional Open Source libraries for Data Science and based on the use of interactive Jupyter Notebooks and/or Google Collab.

Objectives:
- Learn the basics of satellite imagery and EO data interpretation
- Learn about the European Union's EO program Copernicus and the Sentinel satellites
- Learn to download, access and read remote satellite imagery and EO data.
- Learn to process remote satellite imagery and EO data.
- Learn to use cloud platforms such as Google Earth Engine for dealing with large volume of data in the context of satellite imagery and EO data.
- Learn the basics of Artificial Intelligence (AI) and Machine Learning (ML) models.
- Understand how to apply AI and ML in different applications for satellite imagery and EO data.
- Apply ML algorithms to satellite imagery and EO data in a case study relevant in the frame of the UN's SDGs.

References:
[1] "The Global Risks Report 2022", 17th Edition, World Economic Forum, 2022 [https://www.weforum.org/reports/global-risks-report-2022]
[2] "Remote Sensing Technology Market Size (2020-2027)", Grand View Research, 2020 [https://www.grandviewresearch.com/industry-analysis/remote-sensing-technologies-market?utm_source=prnewswire&utm_medium=referral&utm_campaign=ict_23-sept-20&utm_term=remote-sensing-technologies-market&utm_content=rd]
[3] Copernicus program [https://www.copernicus.eu/en] and Copernicus dashboard [https://dashboard.dataspace.copernicus.eu/]
[4] "Sustainable Development Goals", United Nations, 2022 [https://sdgs.un.org/goals]

STUDY LOAD

Type	Hours	Percentage
Hours large group	26,0	20.80
Hours small group	13,0	10.40
Self study	86,0	68.80

Total learning time: 125 h

CONTENTS

Introduction to Earth Observation and Fundamentals of Electromagnetism

Description:
What is remote sensing for Earth observation?
Basics of electromagnetic waves
Interaction of electromagnetic waves with the Earth’s surface
Remote sensing technologies and sensors

Full-or-part-time: 3h
Theory classes: 3h

Earth Observation Systems and Imagery

Description:
Platforms and sensors
Earth observation missions
The Copernicus program and the Sentinel satellites
International Earth observation programs

Full-or-part-time: 2h
Theory classes: 2h

Big Data Exploitation Cloud Platforms

Description:
The new paradigm of Big Earth Data
The Sentinel systems and the Copernicus Program. The Copernicus Open Access Hub
Large scale processing
Exploitation cloud platforms: Google Earth Engine, openEO, WASDI

Full-or-part-time: 3h
Theory classes: 3h

Artificial Intelligence and Machine Learning for Earth Observation

Description:
Artificial Intelligence for Earth Observation
Introduction to machine learning algorithms
Supervised and unsupervised learning
Applications of machine learning in Earth observation

Full-or-part-time: 7h
Theory classes: 7h

Deep Learning and Big Data Analytics for Earth Observation

Description:
Introduction to deep learning
Neural networks and their applications
Big data analytics techniques for Earth observation

Full-or-part-time: 7h
Theory classes: 7h

Applications and Case Studies

Description:
Case studies in environmental monitoring (forests, agriculture, urban areas)
Use of AI and big data for disaster management (earthquakes, landslides, etc.)
Sustainable development goals and Earth observation

Full-or-part-time: 4h
Theory classes: 4h

GRADING SYSTEM

Final exam: 30%
Laboratory sessions (1h/week on average): 20%
Group project: 50%

EXAMINATION RULES.

BIBLIOGRAPHY

Basic:
- Emery, William; Camps Carmona, Adriano José. Introduction to satellite remote sensing : atmosphere, ocean, land and cryosphere applications . Amsterdam : Elsevier, 2017. ISBN 9780128092545.
- Igual Muñoz, Laura; Seguí Mesquida, Santi. Introduction to data science : a Python approach to concepts, techniques and applications . Cham : Springer International Publishing, 2017. ISBN 978-3-319-50017-1.

Complementary:
- Chirag Shah. A Hands-On Introduction to Machine Learning. Cambridge, 2022. ISBN 9781009123303.
- Iddo Drori. The Science of Deep Learning. Cambridge, 2022. ISBN 9781108835084.
- Géron, Aurélien. Hands-on machine learning with Scikit-Learn and TensorFlow : concepts, tools, and techniques to build intelligent systems . Sebastopol, CA : O'Reilly Media, Inc, March 2017. ISBN 9781491962268.

RESOURCES

Other resources:
IEEE GRSS YouTube Channel https://www.youtube.com/c/IEEEGRSS />
Selected playlists:

IEEE GRSS Remote Sensing Training Materials [English] https://www.youtube.com/playlist?list=PLjCH4zaj-OnyQtrrmRzOlJrRk4O5jGV6z />IEEE GRSS Materiales de Capacitación de

Teledetección [Spanish] https://www.youtube.com/playlist?list=PLjCH4zaj-OnzXWLhcer4DvUtGBSbOWXx5 />AMERSIE 2020 school on "Advanced methods for remote sensing information extraction" https://www.youtube.com/playlist?list=PLjCH4zaj-Onx9BWmO13F_ZN1Uraqmd8LT />1st IEEE GRSS IADF School on Computer Vision for Earth Observation https://www.youtube.com/playlist?list=PLjCH4zaj-OnyYSYdRlCAd4VQccfpA6UsD