Remote Sensing

Guide to AI and Data Courses · Part III: Signals, Images and Audio

Satellites and sensors | Spectral bands | Corrections | Classification | Change detection | Related courses

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INTRODUCTION

What Question Does It Ask?

> **What can satellite and aerial images tell us about the Earth?**

Remote sensing extracts information about the Earth without touching it, by measuring **reflected and emitted energy** with sensors on satellites, aircraft or drones. An image is not just a color photo but multiband data, where each band carries a different physical measurement.

At a glance

APPROACH physical sensing and image analysis	**INPUT** multispectral satellite imagery	**OUTPUT** land cover map, change
SUCCESS MEASURE map accuracy, kappa	**MATH LOAD** medium	**DATA NEEDS** plenty; labels limited

A Short History

1858
Nadar photographs Paris from a balloon: the first known aerial photograph.

1960
The first weather satellite, TIROS-1, is launched; clouds are imaged routinely from space.

1972
Landsat 1 is launched: the first civilian program to monitor the Earth in multiple bands.

1978
Seasat becomes the first civilian satellite to collect synthetic aperture radar (SAR) images from space.

2008
The US Geological Survey (USGS) opens the Landsat archive to everyone for free.

2015
Sentinel-2A is launched; Copernicus open data starts an era of frequent, free imagery.

THE COURSE

Core Concepts

Electromagnetic spectrum
Visible, infrared, thermal and microwave bands.

Passive and active
Optical sensors measure sunlight; radar sends its own signal.

Types of resolution
Spatial, spectral, temporal and radiometric.

Spectral signature
Water, plants and soil reflect differently in each band.

Band indices
NDVI for vegetation, NDWI for water.

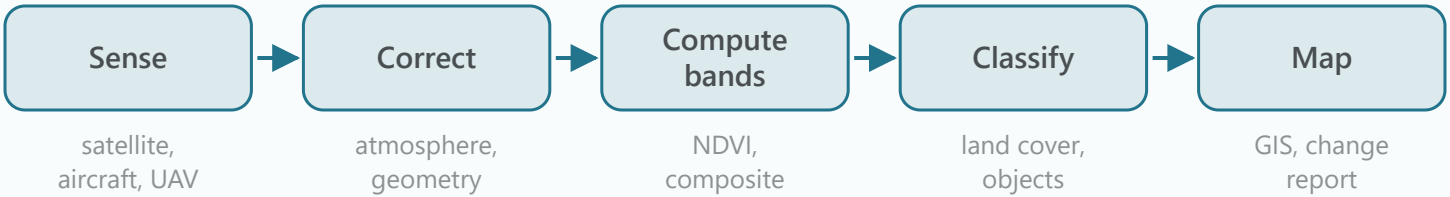
Corrections
Atmospheric, terrain and geometric correction.

Land classification
Labeling each pixel as forest, field, urban or water.

Change detection
Comparing images from different dates.

THE COURSE

A Typical Workflow



Example: Sentinel-2 images taken before and after a forest fire are corrected for the atmosphere. A burn index is computed from the near-infrared and shortwave infrared bands; the difference between the two dates reveals the burned area. The result is measured in hectares and drawn on a map.

THE COURSE

What Does the Course Cover?

1. Electromagnetic radiation and surface interaction
2. Sensors, platforms and types of resolution
3. Radiometric and atmospheric correction
4. Geometric correction, coordinate systems, projections
5. Image enhancement and colour composites
6. Spectral indices: NDVI, NDWI
7. Supervised and unsupervised land-cover classification
8. Accuracy assessment and ground truth
9. Change detection and time-series analysis
10. Thermal sensing and LiDAR
11. Radar (SAR) imagery and interferometry
12. Deep learning for satellite imagery

Skills you will gain

raster and vector layers in QGIS

time series in Google Earth Engine

processing imagery with GDAL and rasterio

land-cover maps with accuracy tables

interpreting indices such as NDVI

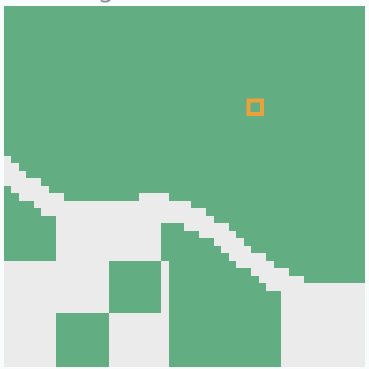
A typical semester; the order and coverage vary between universities.

TRY IT

Measuring Forest Loss from Space

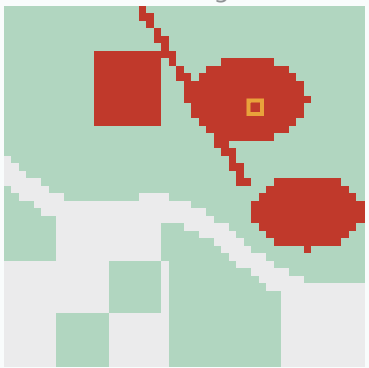
Two satellite images of the same area, from two dates, have red and near-infrared (NIR) bands. Find vegetation with NDVI, slide the threshold and measure how many hectares of forest were lost; click a pixel to see its value.

2019: vegetation



vegetation

2019 → 2024 change



loss gain cloud

Image | NDVI | **Change** | Mask clouds

Vegetation threshold: NDVI ≥ **0.50**

Vegetation cover: 77% → 61%
Lost: **33.1 ha** (**21%** of 2019 cover)
Gained: 0.0 ha

Selected pixel (30×30 m), NDVI = (NIR − R) / (NIR + R):
2019: (0.44 − 0.04) / (0.44 + 0.04) = **0.83**
2024: (0.27 − 0.19) / (0.27 + 0.19) = **0.18**

Remote sensing turns bands the eye cannot see into a **physical indicator**. The course teaches band ratios, masking disturbances such as clouds, and measuring change as area.

CONTEXT

Prerequisites

Courses worth knowing before this one, and why they are needed.

Course	Why it is needed
Image Processing	multispectral images, correction
Computer Vision	land cover classification, change detection
Physics	electromagnetic waves, reflection and absorption
Geographic information systems	coordinate systems, map projections and layers
Programming	large array and file operations in Python

CONTEXT

Are You Ready for This Course?

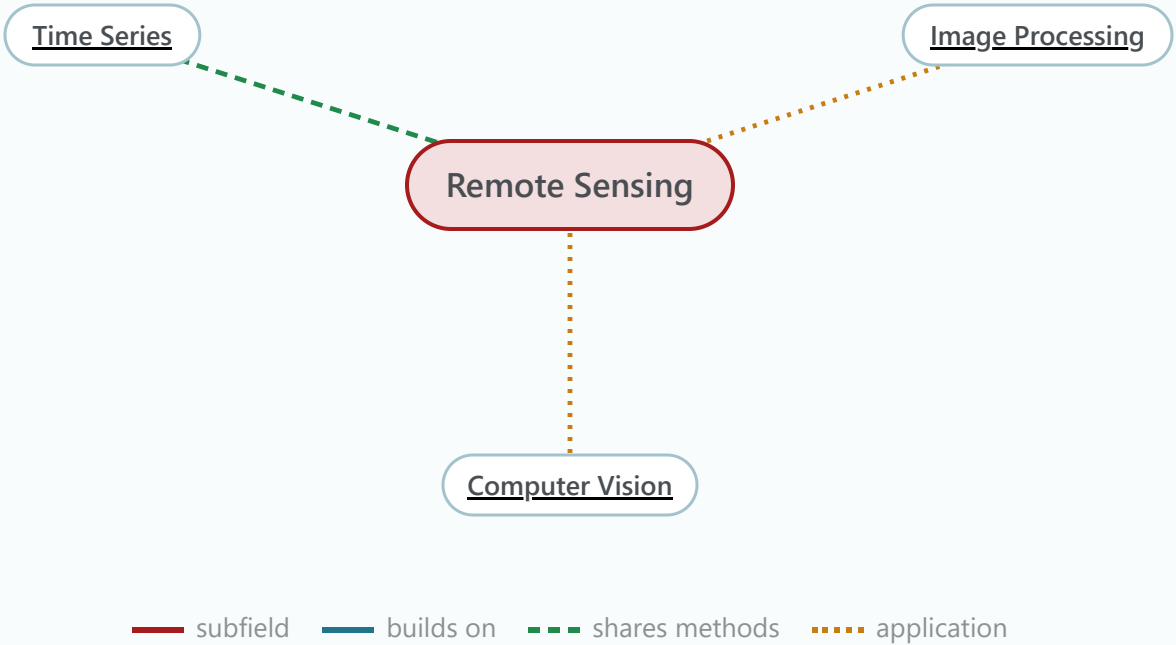
Ask yourself; for every "no", the right-hand column shows where to start.

Ask yourself	If not, start with
Can you explain the visible and infrared parts of the electromagnetic spectrum?	Electromagnetic waves from high-school physics
Can you explain latitude/longitude versus projected (metre) coordinates?	A short introductory GIS tutorial with QGIS
Can you apply a histogram and thresholding to an image?	Image Processing
Can you train a classifier and interpret its confusion matrix?	Machine Learning

If you can say "yes" to most of these, you are ready; one or two gaps can be closed during the semester.

CONTEXT

Neighbouring Courses



OVERLAP

Overlapping Courses

Relation	Course	Shared ground
application	This course applies the methods of Image Processing	multispectral images, correction
application	This course applies the methods of Computer Vision	land cover classification, change detection
shares methods	Shares methods with Time Series Analysis and Forecasting	multitemporal image series

DIFFERENCES

Where It Differs (1/2)

Criterion	Remote Sensing	Image Processing	Computer Vision
Core question	What can satellite and aerial images tell us about the Earth?	How is an image enhanced, transformed and divided into regions?	How does a computer understand what is in an image or a video?
Approach	physical sensing and image analysis	pixel-level transformations	extracting meaning from images
Input	multispectral satellite imagery	image	image or video
Output	land cover map, change	processed image or regions	label, box, depth, 3D structure
Success measure	map accuracy, kappa	visual quality, PSNR	accuracy, mAP, IoU
Math load	medium	medium: convolution, Fourier	high: geometry, linear algebra
Data needs	plenty; labels limited	little; learning not required	many labeled images

- **Image Processing:** Image processing provides the general methods; remote sensing applies them to multiband satellite images that carry physical measurements.
- **Computer Vision:** Vision recognizes objects in ordinary photos; remote sensing maps the Earth using spectral signatures and location.

DIFFERENCES

Where It Differs (2/2)

Criterion	Remote Sensing	Time Series	Medical Imaging
Core question	What can satellite and aerial images tell us about the Earth?	How do we find structure in measurements over time and forecast the future?	How do X-ray, CT and MRI images help diagnosis and treatment?
Approach	physical sensing and image analysis	time-dependent statistical models	image processing plus clinical knowledge
Input	multispectral satellite imagery	timestamped measurements	CT, MRI, X-ray, ultrasound
Output	land cover map, change	forecast, trend, seasonality	segmentation, measurement, diagnostic suggestion
Success measure	map accuracy, kappa	forecast error (MAE, RMSE)	sensitivity, specificity, Dice
Math load	medium	medium-high	medium-high
Data needs	plenty; labels limited	long history	little; labels are expensive

- **Time Series:** Time series analysis provides the general methods; remote sensing tracks change in images of the same place over years.
- **Medical Imaging:** Both treat an image as a physical measurement; medical imaging measures the body, remote sensing the Earth.

PRACTICE

Applications

Agriculture
Crop health, yield prediction, irrigation.

Forestry
Burned areas, deforestation monitoring.

Disaster management
Damage maps after earthquakes and floods.

Urban planning
Construction and urban sprawl.

Climate and environment
Monitoring glaciers, sea surface and drought.

Defense
Reconnaissance and target area analysis.

PRACTICE

Risks and Ethics

Surveillance and privacy

High-resolution satellite and drone imagery can track people's homes, vehicles and movements without consent.

Maps without ground truth

A classification map never checked in the field can mislead farming or disaster decisions despite high reported accuracy.

Clouds and shadows

Unmasked clouds and shadows look like forest loss or flooding in change detection.

Models that do not transfer

A model trained on European data fails silently in other climates and farming patterns; each region needs validation.

In depth: Explainable AI and AI Ethics.

PRACTICE

Tools and Datasets

Tools and libraries

Google Earth Engine · QGIS · GDAL · rasterio · ESA SNAP · TorchGeo

Well-known datasets

Landsat archive · Sentinel-1 and Sentinel-2 · EuroSAT · BigEarthNet · SpaceNet · UC Merced Land Use

Satellite imagery is **plentiful and free**, but accurate labels are scarce: ground truth means going into the field.

PRACTICE

Common Misconceptions

Common belief	In fact
A satellite image is an ordinary color photo.	It also has infrared, thermal and radar bands that the eye cannot see.
Higher spatial resolution is always better.	For wide areas and frequent revisits, medium resolution is often more suitable.
If there are clouds, the satellite sees nothing.	Optical sensors cannot; radar (SAR) sees through clouds and at night.
This is just an image processing course.	Sensor physics, the atmosphere, map projections and field validation are also part of it.

NEXT STEPS

After This Course

Courses that build on or extend this one

This course is mostly an end point: it builds on the others.

Related careers

Remote sensing specialist | GIS specialist | Agricultural technology engineer | Environmental and climate data analyst | Geomatics engineer

Remote sensing is image processing and computer vision applied to the Earth; it joins with time series analysis and big data systems. From here you can move on to climate and agricultural data science, geographic information systems, or satellite image analysis with deep learning.

NEXT STEPS

Further Reading

- Lillesand, Kiefer and Chipman, *Remote Sensing and Image Interpretation*, 7th ed., Wiley, 2015.
- Jensen, *Remote Sensing of the Environment: An Earth Resource Perspective*, 2nd ed., Pearson, 2007.
- Campbell and Wynne, *Introduction to Remote Sensing*, 5th ed., Guilford Press, 2011.
- Richards, *Remote Sensing Digital Image Analysis*, 5th ed., Springer, 2013.

The End

Chapter 21: Remote Sensing

← Previous chapter · Map of the field · Next chapter →