AI4EO

Special Topics in Applications (AIL861)
Artificial Intelligence for Earth Observation
Lecture 1

Different Types of Sensing

- ✔ Different technologies can be used:
- ❑ In-situ sensing
- ❑ Proximal sensing
- ❑ Remote sensing

- ✔ These technologies can acquire different kinds of measurements with different properties.

- ✔ Depending on the application, each specific application can have different importance.

Remote sensing

- ✔ Sensing from a great distance
- ✔ Distance between the object and the sensor >> dimension of the sensor
- ✔ Satellite, aircraft, UAV

Image from
https://www.esa.int/Education/4._The_polar_orbit

Remote Sensing / Earth Observation

- ✔ Remote sensing systems are capable of acquiring signals and images related to the atmosphere and the Earth's surface.

- ✔ The possibility of acquiring this data from space allows to conduct analyses at different scale factors, both local and global.

- ✔ The availability of different types of sensors (passive sensors, radar sensors,laser sensors, etc.) allows us to address a wide range of applications linked to the monitoring and study of the atmosphere and the surface terrestrial.

Formalizing the Definition

Less formal: Obtaining information about a object by means of a sensor not in contact with it.

More formal: Acquiring information about a object through the identification and measurement of the characteristics possessed by the electromagnetic field emitted and/or diffused by the object itself..

Let’s think about applications of remote sensing / Earth observation?

Applications

- ✔ Environmental monitoring
- ✔ Infrastructure monitoring
- ✔ Climate change
- ✔ Agriculture and food security

Challenges

- ✔ Challenge 1: Many applications

Environmental monitoring

- ✔ Forestry
- ✔ Urban area
- ✔ Vegetation
- ✔ Sea and rivers
- ✔ Glaciers and ice

Forestry

- ✔ Species classification
- ✔ Deforestation detection
- ✔ Biomass and volume detection
- ✔ Insect infection detection

Species classification

- ✔ Assume species constant over a time period, how many images should we use over this time period?

Species classification

- ✔ Classification or segmentation?

Species classification

- ✔ Can we use co-occurrence information?

Species classification

- ✔ What if we had a species map from a while back?

Deforestation detection

- ✔ How many images?

Deforestation detection

- ✔ Classification or segmentation?

Deforestation detection

- ✔ What if we had a deforestation map from a while back?

Biomass volume detection

- ✔ How many images?
- ✔ What type of ML problem?

Sea monitoring

- ✔ Ocean color
- ✔ Harmful algal bloom detection
- ✔ Pollutant detection
- ✔ Temperature detection

Infrastructure Monitoring

- ✔ Post-Disaster Monitoring.
- ✔ Monitoring urban sprawl, informal settlements.
- ✔ Investment management of financial institutes.
- ✔ Solar panels.

Climate

- ✔ Segmenting glaciers.
- ✔ Tracking deforestation and drought.
- ✔ How meteorological variables impact land surface?

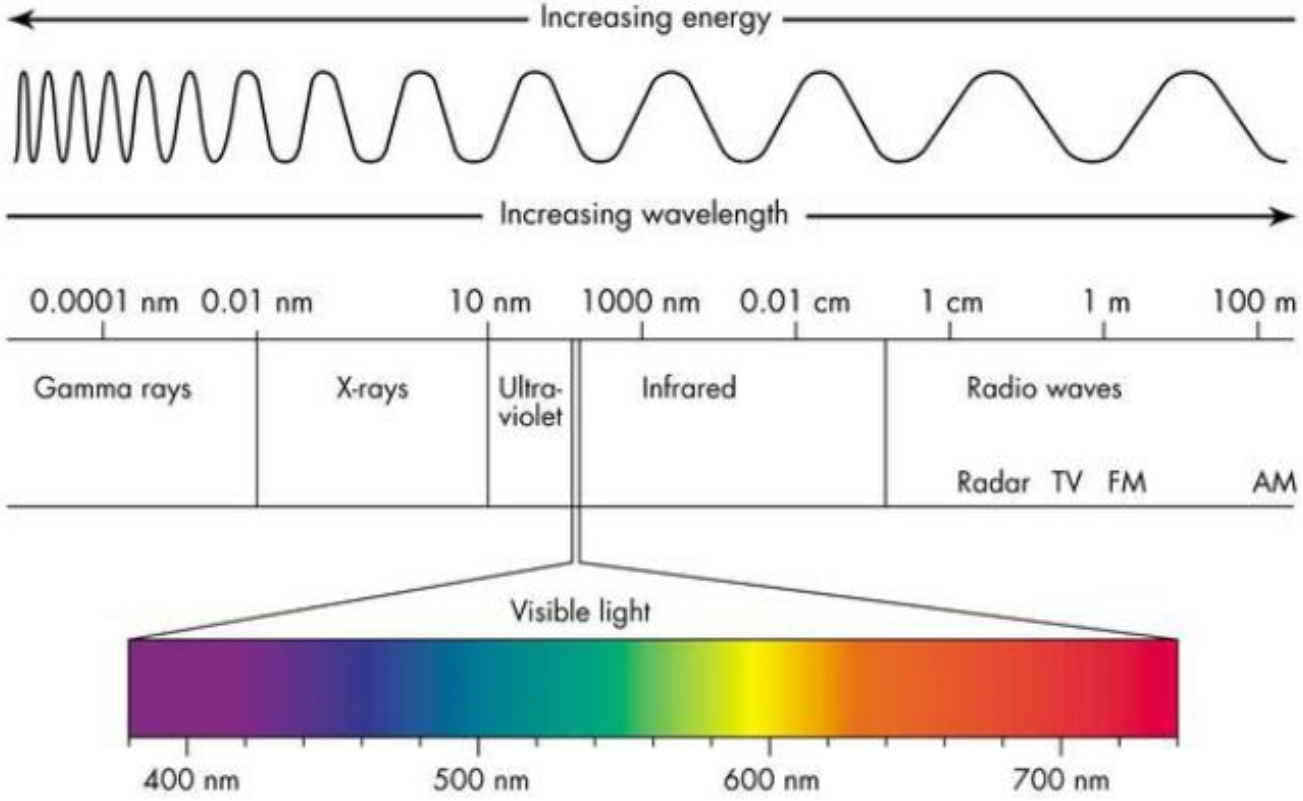
Agriculture

- ✔ Monitoring crop-health
- ✔ Crop-cycle
- ✔ Soil moisture detection

What is a remote sensing sensor?

Electromagnetic Spectrum

- ✔ The electromagnetic (EM) spectrum consists of a continuous set of radiations
- ✔ Sorted by wavelength (or frequency).



Passive and Active

Two different paradigms

Passive Sensors

- ✔ Remote sensing systems which measure energy that is naturally available..
- ✔ Passive sensors can only be used to detect energy when the naturally occurring energy is available.
- ✔ For all reflected energy, passive sensing take place during the time when the sun is illuminating the Earth.
- ✔ All materials on Earth absorb or reflect (some, like water transmit) solar energy in the EM spectrum range between 0.4 and 3 μm.

Active Sensors

- ✔ The active systems, instead of using the energy emitted by the Sun and the Earth (passive remote sensing), emit EM waves and illuminate the light themselves surface to be studied.

- ✔ We operate with radar sensors in the microwave region. The advantage of microwaves lies in their ability to "penetrate" clouds, fog and rain (apart from the absorption band of the water vapor).

- ✔ Such active sensors are not dependent on the presence of solar radiation.

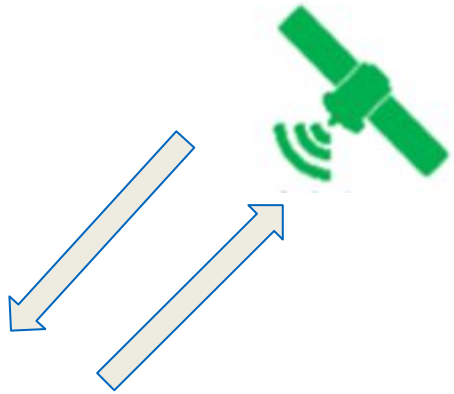


Image From a Passive Sensor

Image From an Active Sensor

Image From an Active Sensor

- ✔ Visual saliency: less.
- ✔ Noise: more.
- ✔ Side view geometry: Foreshortening, layover, shadow.

Challenges

- ✔ Challenge 2: Active and passive sensors capture images with significantly different characteristics.

Are all passive sensor similar?

Not all passive sensors are similar. Passive sensors are remote sensing instruments that do not emit their own energy, but instead rely on the natural energy from the sun or other sources to illuminate the Earth's surface and atmosphere. The different types of passive sensors can vary in terms of their spectral, spatial, and temporal resolution, as well as the type of information they are able to capture.

Some common types of passive sensors include:

Optical sensors: Optical sensors, such as satellite-based remote sensing systems, capture visible and near-infrared radiation reflected from the Earth's surface to produce images. They are commonly used for applications such as vegetation monitoring, land use mapping, and environmental monitoring.

Radar sensors: Radar sensors use radio waves to measure the reflection and scattering of signals from the Earth's surface. They are able to penetrate clouds and produce images under all weather conditions, making them useful for applications such as topographic mapping and disaster management.

Thermal infrared sensors: Thermal infrared sensors measure the radiated energy emitted by the Earth's surface in the infrared region of the electromagnetic spectrum. They are commonly used for applications such as urban heat mapping, agriculture monitoring, and mineral exploration.

Each type of passive sensor has its own strengths and limitations, and the choice of sensor will depend on the specific requirements and goals of the remote sensing application. Thus, it can be concluded that not all passive sensors are similar, and each one has its unique characteristics and capabilities.

Modalities or Sensors

- ✔ Many modalities:
- ❑ Multi-spectral
- ❑ Hyperspectral
- ❑ Synthetic Aperture Radar (single band, multi-band, polarimetric)
- ❑ LiDAR

Different types of satellites

- ✔ Geostationary (distance 36000 km) - continuous observation with a spatial resolution of few hundred meters or Kms
- ✔ Polar (few hundred kms) – observation every few days/ weeks
- ✔ Constellation of polar
- ✔ Aircraft / UAV – observation on demand

Resolutions

- ✔ Spatial resolution
- ✔ Spectral resolution
- ✔ Temporal resolution
- ✔ Radiometric resolution

Spectral resolution

- ✔ Ability of sensors to distinguish between wavelength
- ✔ Water and vegetation – coarse
- ✔ Different rock types – we need fine spectral resolution.

Multi-spectral sensors

- ✔ Similar to those we work in CV
- ✔ 3-4 bands, sometimes slightly more
- ✔ Spatial resolution can vary (few cms/pixel to few kms/pixel)

Multi-spectral sensors

Multi-spectral sensors

- ✔ You have a few 3 band images. You do not have any training dataset (or you have a very small dataset). What can you do?

Multispectral sensors

Sensor	Year	Geometrical Resolution (m/pixel)
Landsat-1	1972	60
Landsat-4	1982	30
SPOT-1	1986	20 and 10
Quickbird	2001	0.65
SPOT-5	2002	2.5,5, and 10
Pleiades	2011/12	0.50
Landsat-8 OLI	2013	30 and 15
Sentinel-2	2015/17	10 - 60

Hyperspectral sensors

- ✔ Detect hundreds of very narrow spectral bands throughout the visible, near-infrared, and mid-infrared portions of the electromagnetic spectrum.

- ✔ Their very high spectral resolution facilitates fine discrimination between different targets based on their spectral response in each of the narrow bands.

Hyperspectral sensors

- ✔ You have a hyperspectral image with 200 bands. For your specific application, indeed many bands are useful. Will the previous solution devised for multispectral images work here?

Challenges

- ✔ Challenge 3: Even within same category of sensor, there can be significant variation in the characteristics of the individual sensor.

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Remaining challenges?

Remote sensing data characteristics

- ✔ Remote sensing data are often multi-modal
- ✔ Remote sensing data are geo-located, however often in an imprecise manner.
- ✔ Time variable is often very important

Outside academia and space agencies

Several companies

- ✔ VTT Research Finland: forestry
- ✔ Airbus defense and Space
- ✔ E-Geos Italy: several applications including burned area monitoring
- ✔ GAF: Natural resources and raw materials, environment monitoring, emergency management
- ✔ Microsoft AI for Earth

Course content?

Remote sensing or Machine Learning ?

✔ Not a course for Remote Sensing.

✔ Not another course for Machine Learning.

Evaluation

- ✔ Traditional evaluation:
- ❑ Mid sem (15)
- ❑ End sem (25)
- ❑ Assignments (10)

- ✔ Presenting a paper (15)

- ✔ Project (35 + up to 5 bonus)