

The background of the slide is a mosaic of small, square tiles, each containing a different aerial satellite image of various landscapes, including urban areas, forests, and agricultural fields. The tiles are arranged in a grid pattern, creating a textured, multi-colored background.

# PyData Rome

1st Meeting, 30 November 2022

BinarioF, Rome - Italy

## Deep Learning for Land Use and Land Cover Classification

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Luigi Selmi

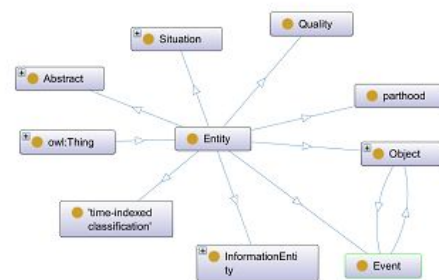
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# Luigi Selmi



Working Experience: software engineer in private enterprises and public research institutions in Italy, Switzerland, Germany

Academic Background: Atmospheric Physics and Remote Sensing (Sapienza University of Rome)



# Outline

- The Problem
  - Land Use & Land Cover Classification
- The Physics
  - Reflectance spectra
- Copernicus
  - Sentinel-2 and the MSI Instrument
  - Open Access Hub and Copernicus DIAS
- Deep Learning
  - Deep Learning architectures
  - The EuroSAT dataset
  - Data augmentation techniques
  - Fine-tuning
  - Model evaluation
  - One more validation test
- Conclusion

# Land Use / Land Cover Classification

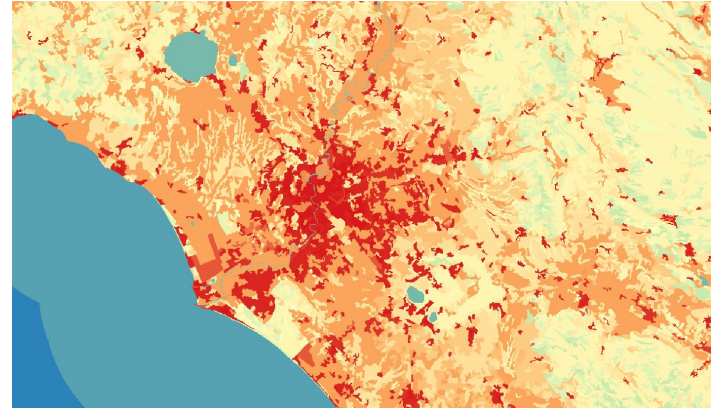
Goals:

Resource planning and monitoring

Change detection

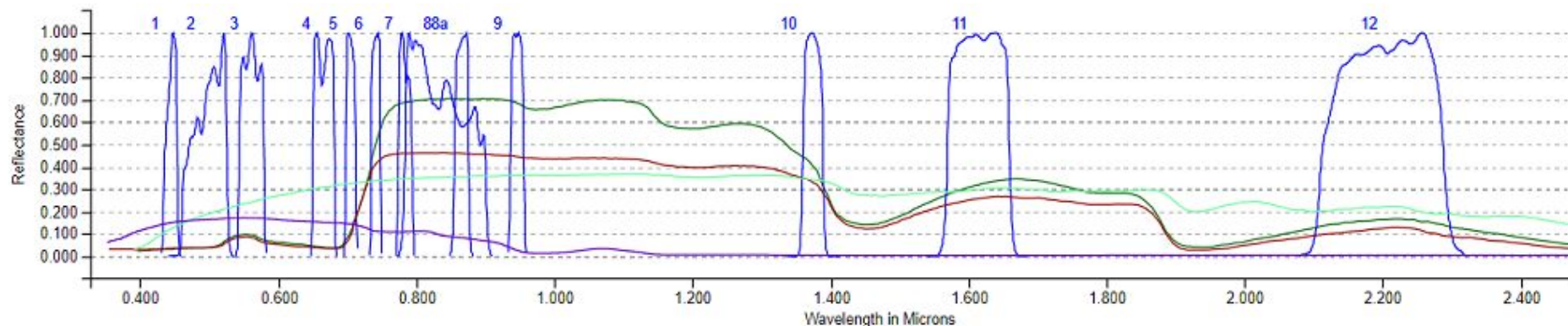
Example:

Corine Land Cover (44 classes, 3 levels)



Corine 2018 100m

# Reflectance spectra



## Bands

■ Sentinel 2A MSI

## Spectra

■ Lawn Grass ■ Aspen Leaf 1 ■ Dry Grass ■ Turbid Water

# Copernicus Sentinel-2 and the MSI Instrument

Constellation of 2 satellites  
in polar orbit at 786 km  
altitude.

Revisit time: 5 days

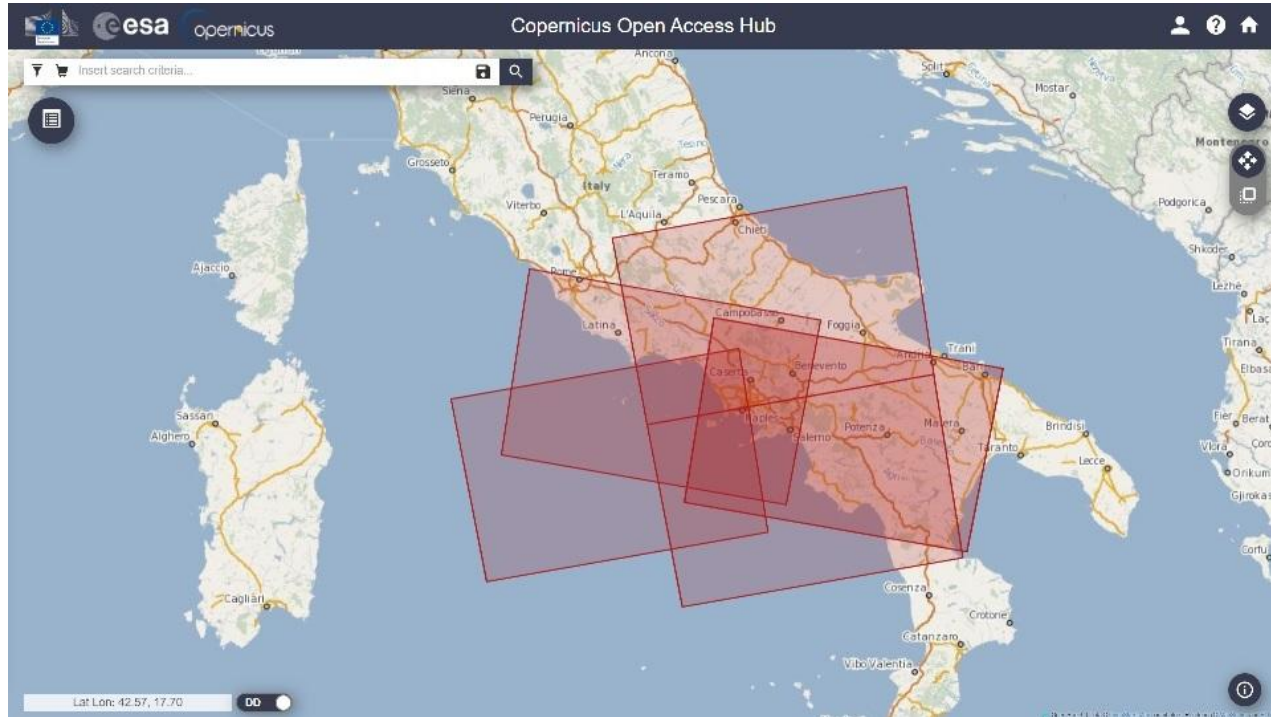
Swath: 290 km

Multi-Spectral Imager with  
13 bands from VIS to SWIR

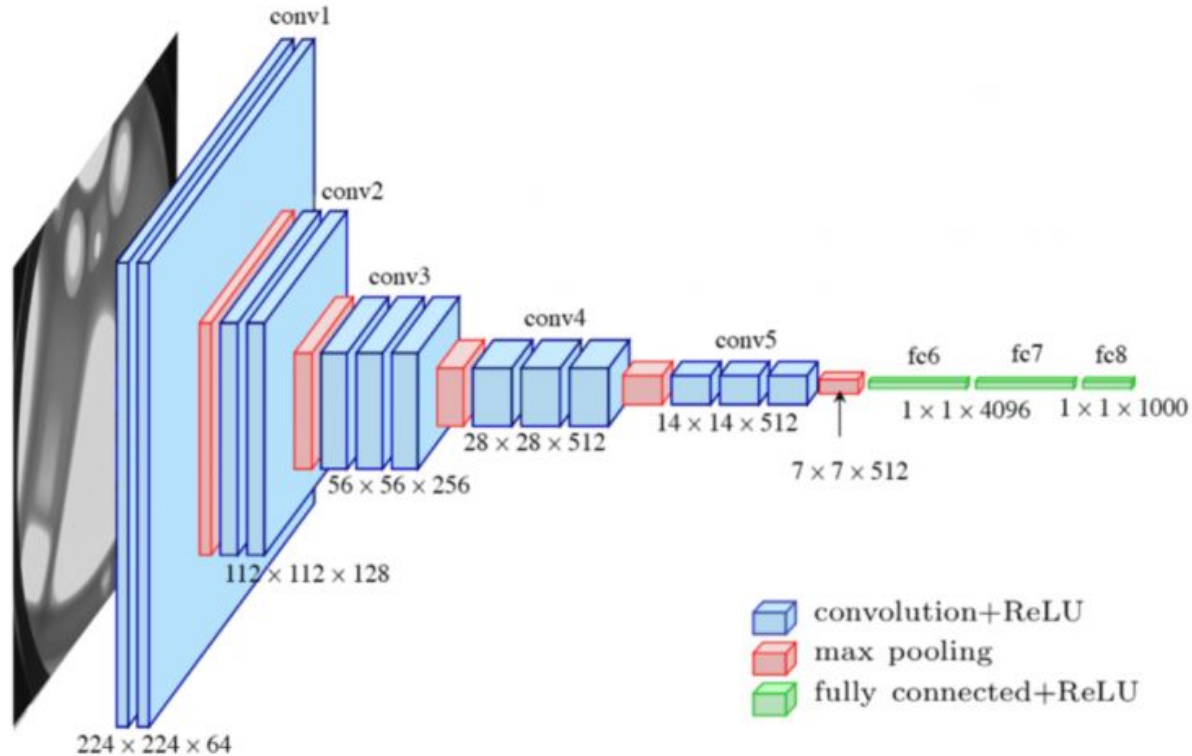
Res.: 10m RGB (60m for  
other bands)



# Copernicus Open Access Hub and DIAS



# Deep Learning Architectures

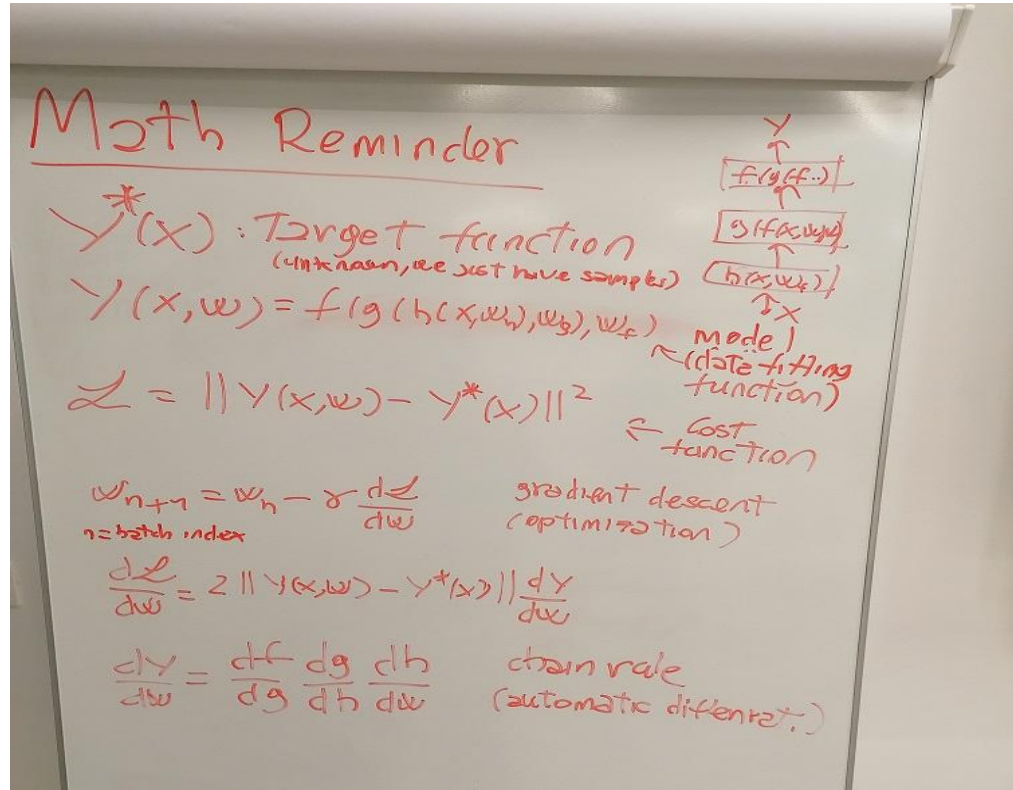




# Deep Learning Math

DL Math is not that difficult. What matters is the implementation.

PyTorch uses automatic differentiation to compute the gradient of the cost function



# The EuroSAT dataset

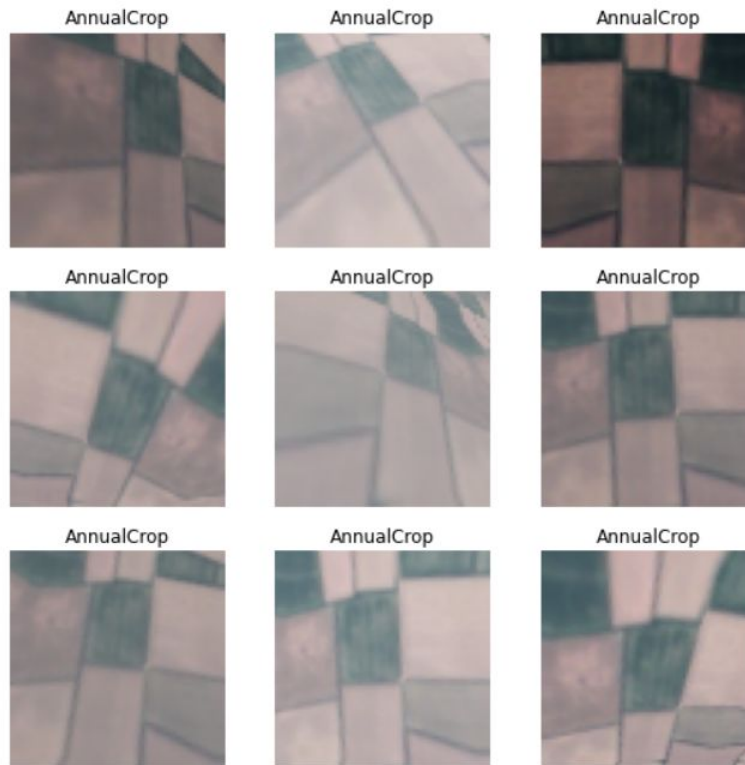
10 Classes: Forest , Pasture, Herbaceous Vegetation, Annual Crop, industrial, Residential, Permanent Crop, Highway, Sea Lake, River

Patches from Sentinel-2 imagery: 27000 64x64 RGB images, 2000-3000 per class



# Data Augmentation

Affine transformations + Noise



# Fine-tuning the ImageNet dataset

The model is trained over the ImageNet dataset, a set of 1.200.000 images from 1000 classes.

The model is fine-tuned using the much smaller EuroSAT images by “freezing” all the model parameters but the last layers.

Only 2 millions parameters to be learnt for each epoch instead of more than 25 millions.



# Model evaluation

Training set: 80%

Validation set: 20%

## Misclassifications:

Annual Crop, Permanent Crop: 15

Industrial, Residential: 12

Sea Lake, Forest: 11

Herbaceous Vegetation, Permanent Crop: 9

Highway, River: 7

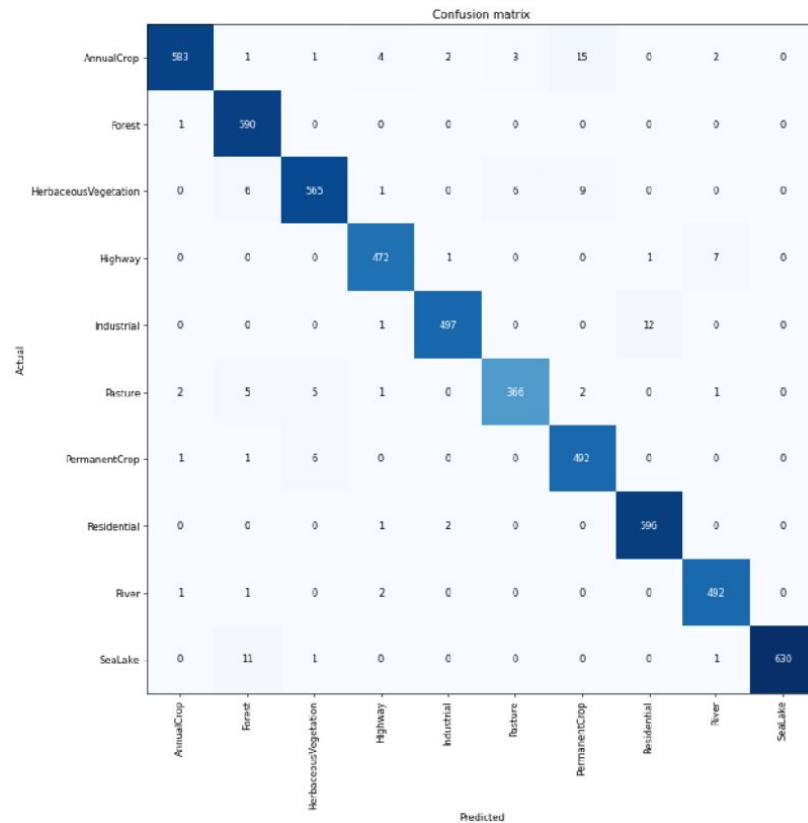
Herbaceous Vegetation, Forest: 6

Herbaceous Vegetation, Pasture: 6

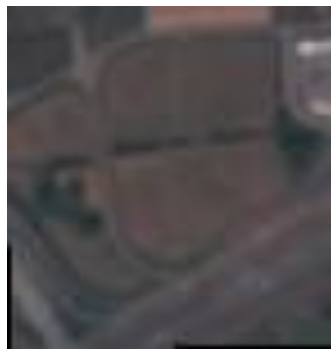
Permanent Crop, Herbaceous Vegetation: 6

Pasture, Forest: 5

Pasture, Herbaceous Vegetation: 5



# Additional tests



July 2019

Prediction: Highway; Probability: 0.9980

[4.8410e-04, 1.3392e-06, 1.5634e-04, 9.9796e-01,  
1.9808e-04,  
1.3962e-04, 8.8622e-04, 4.6300e-05, 1.1766e-04,  
1.2730e-05]



Aug. 2021

Prediction: Industrial; Probability: 0.7301

[2.8591e-04, 3.4131e-06, 1.4427e-04, 2.6680e-01,  
7.3014e-01,  
3.1067e-05, 1.4392e-04, 3.6543e-04, 2.0304e-03,  
5.0807e-05]

# Conclusion

- Satellite imagery is a relevant resource for LULC classification tasks
- A CNN ResNet with “only” 50 layers provides a good accuracy
- A LULC map can be produced quickly in a cost-effective way
- The result may be improved by using all the 13 MSI bands, Sentinel-1 SAR images and a larger dataset for fine-tuning.

Blog post with link to the GitHub repository:

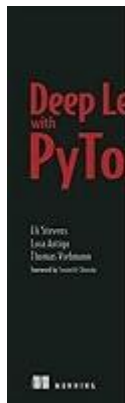
<https://www.luigiselmi.eu/eo/lulc-classification-deeplearning.html>

# References

Links to many free online textbooks about Remote Sensing and Deep Learning are available on my website

<https://www.luigiselmi.eu/bookshelf>

Other books on the market are:



**Yann Le Cun**

Prix Turing

**Quand  
la machine  
apprend**

La révolution des neurones artificiels  
et de l'apprentissage profond





# Thanks for your attention!

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## Connecting data that matters

Data is not a scarce resource  
In order for it to be useful and become information  
and knowledge we need to unearth the gems  
buried under gigabytes of waste

Data is not a scarce resource. In order for it to be useful and become information and knowledge we need to unearth the gems buried under gigabytes of waste and connect them in a mosaic, something that we can use and share. We have decided to focus on data that matters. Nowadays many datasets are released by scientific institutions, governmental organizations and communities under an open data license. Those datasets can help to address the challenges we have in front of us, improve our work and products, and help us to plan our future the way we want.

### Areas of Expertise

We work on projects in the areas described in the following sections

 datiaperti