

# The rise of Artificial Intelligence for Earth Observation



Nicolò Taggio  
*AI researcher*  
*GeoAnalytics Team*  
Planetek Italia

# AGENDA

## AI

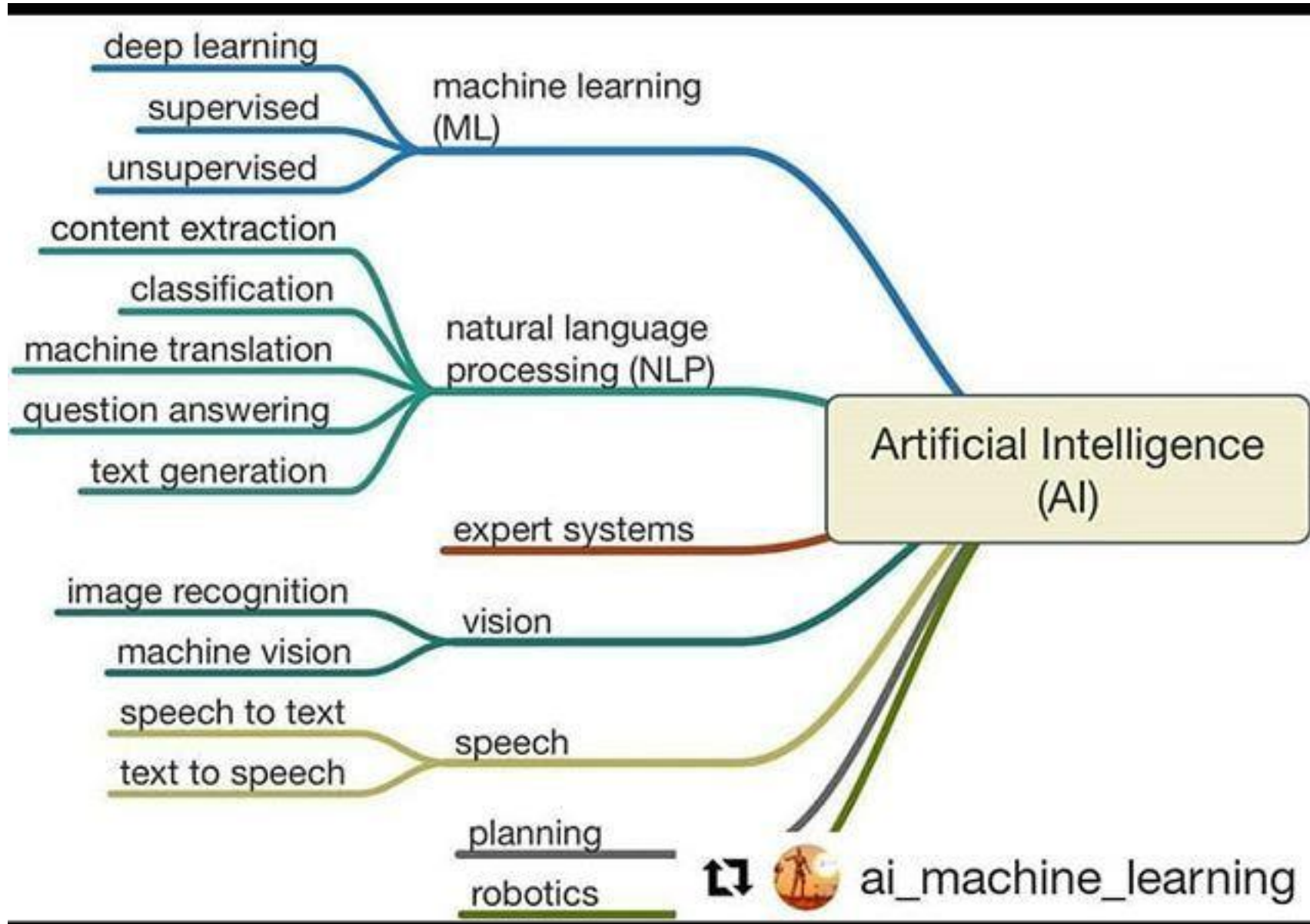
- Basic Concepts
- Algorithm architectures

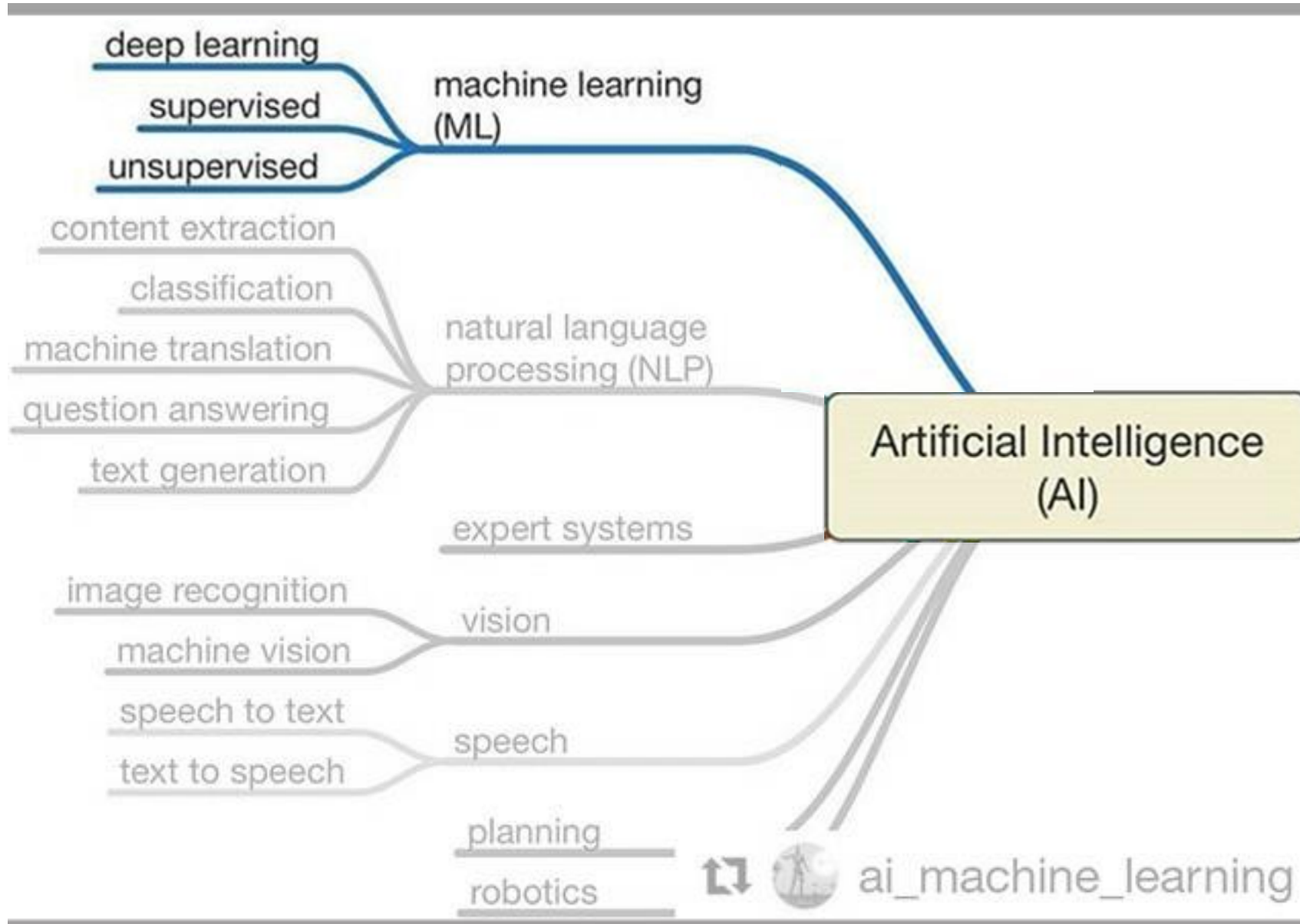
## AI4EO

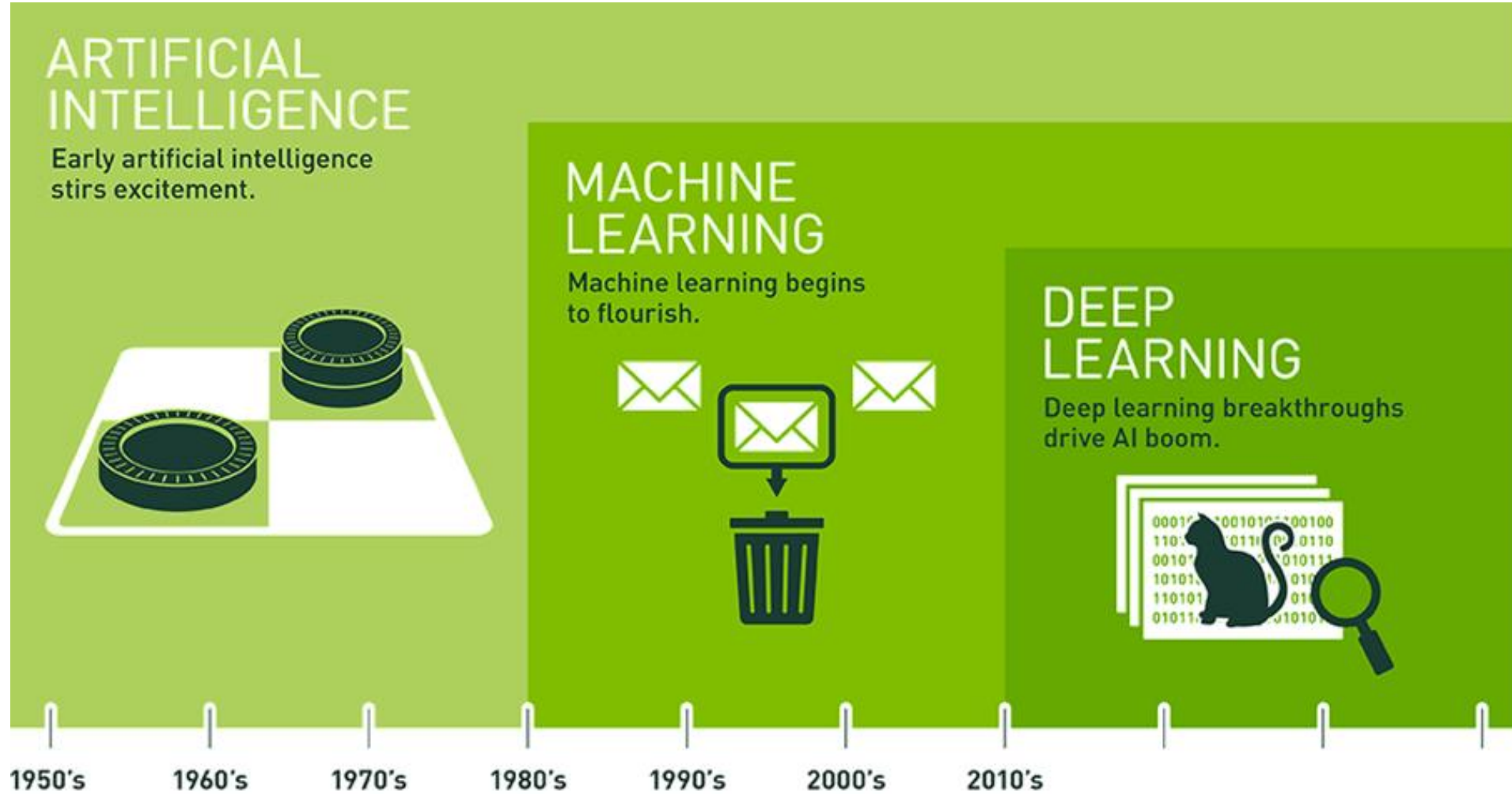
- EO Data
- EO Applications

## CRITE

- AI to map shadowed coffee plantations using multi-temporal and multi-sensor EO images









**Machine Learning  
and  
Deep Learning**

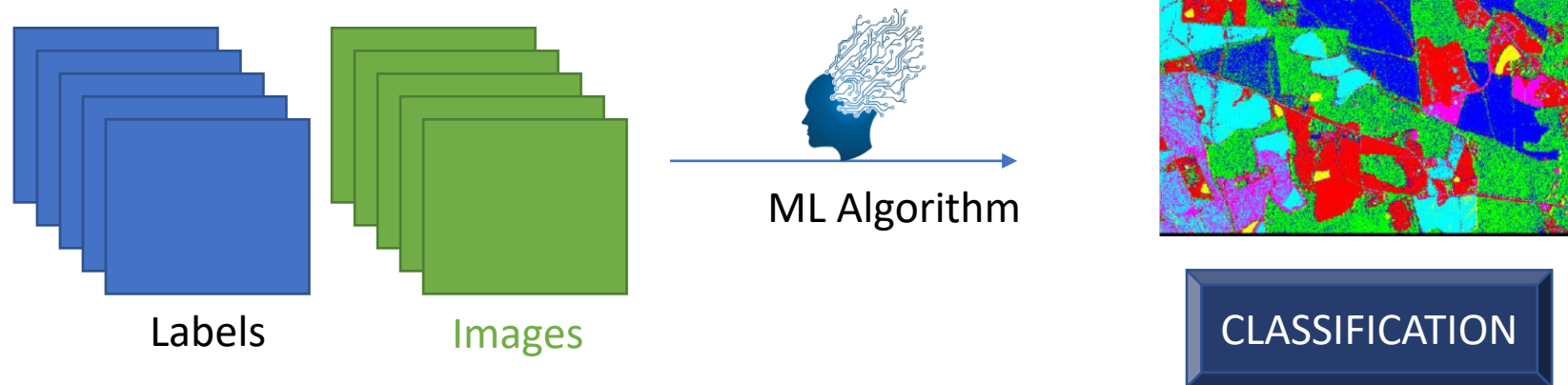
**Basic concepts**

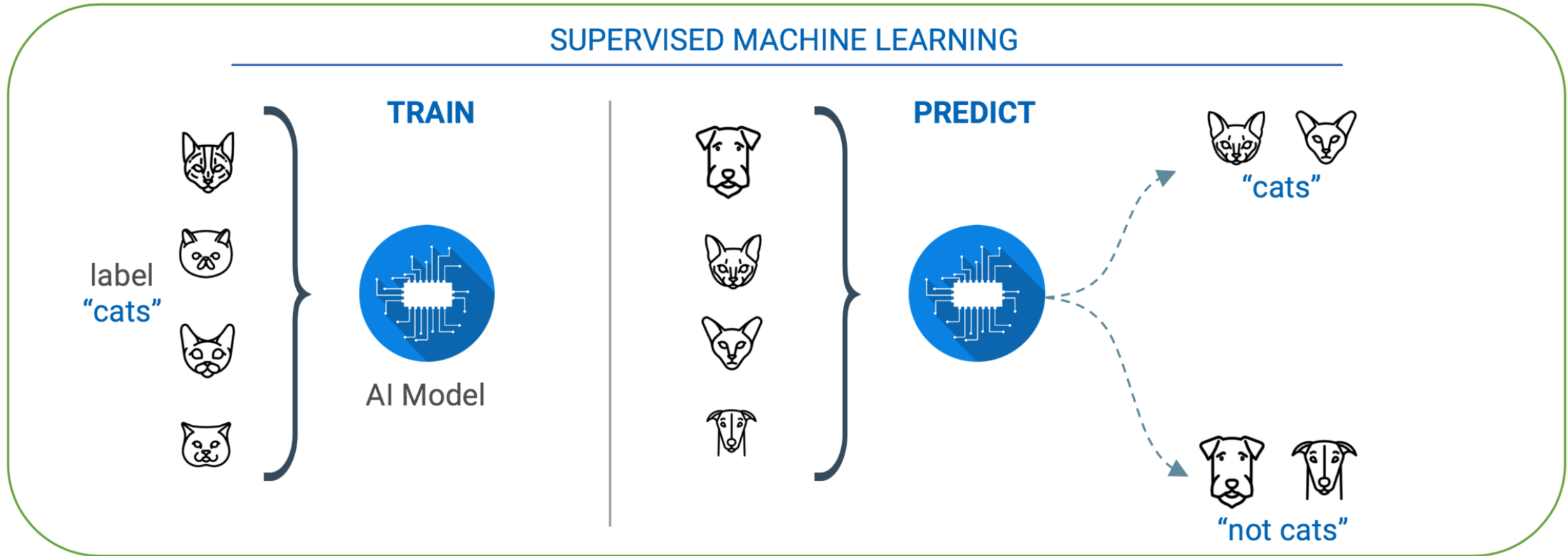
In **supervised learning**, the training data that is fed to the algorithm already includes the desired solutions, called labels.

A typical supervised learning task is classification. To perform a classification of land cover, a multispectral image is used.

In this process, you select pixels that represent patterns or land cover features that you recognize, or that you can identify with help from other sources, such as aerial photos, ground truth data, or maps. Knowledge of the data, and of the classes desired, is required before classification.

The algorithm is trained with many pixels of the different desired land cover classes and, based on that training, classifies the multispectral image.



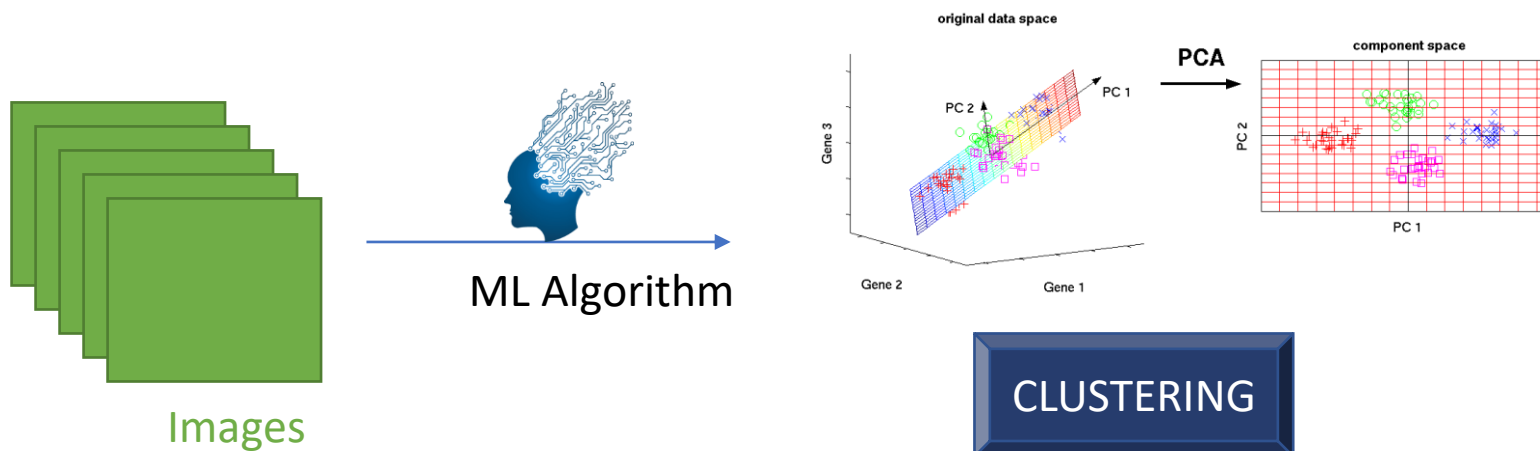


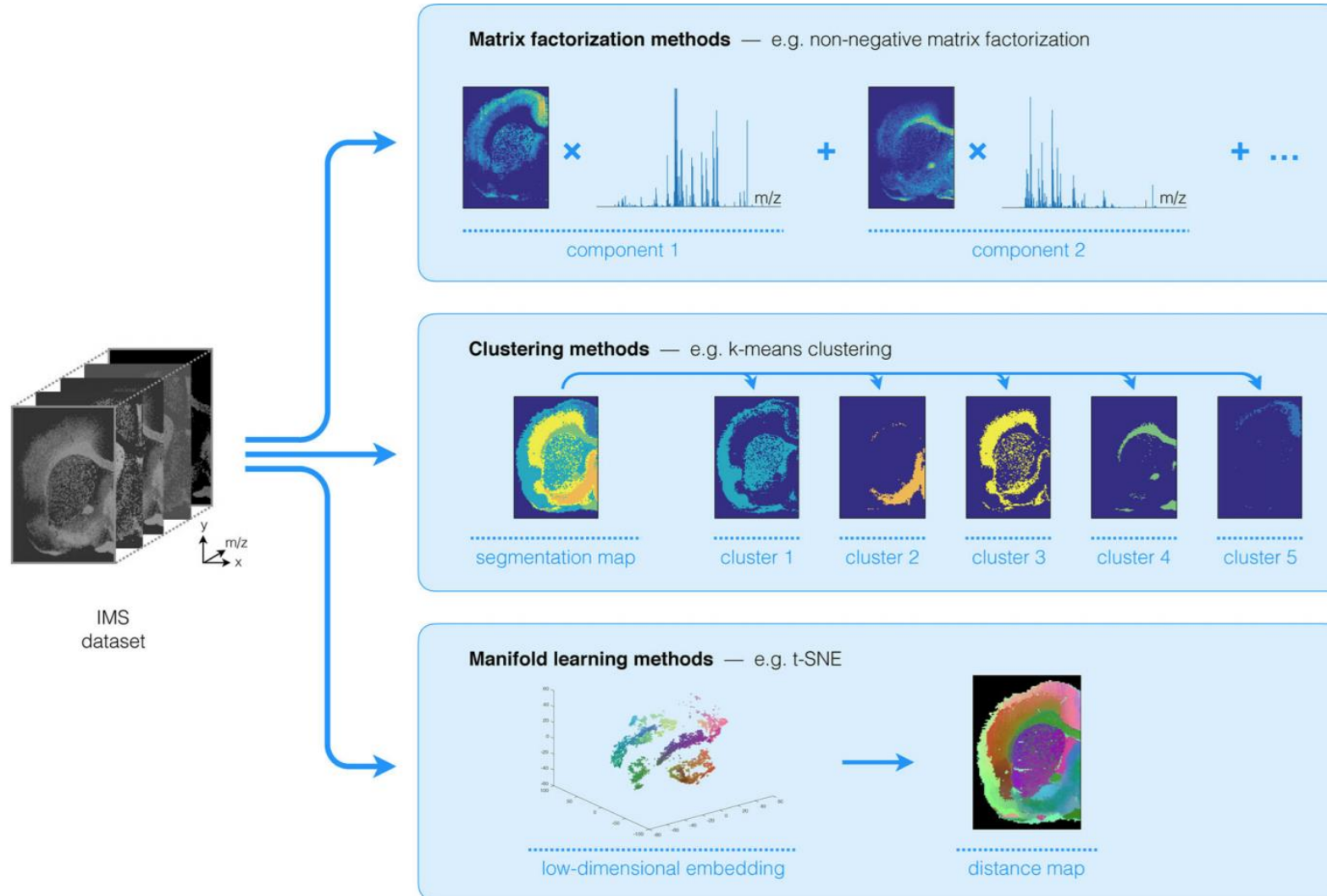


In **unsupervised learning**, the system tries to learn without first training the data. In the land cover classification example, the algorithm attempts to divide the multispectral image into a set number of classes based solely on the data in the image.

The output classes are determined by the distribution of the data in the image, not by the training data of desired land cover classes that is provided in Supervised learning. The analyst then attaches meaning to the resulting classes.

Unsupervised training is dependent upon the data itself for the definition of classes. This method is usually used when less is known about the data before classification.

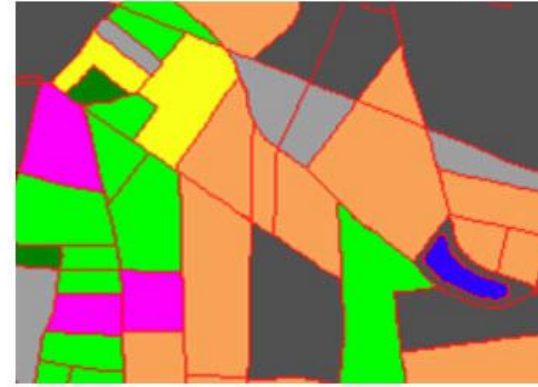




# Pixel Based and Object Based



Pixel based



Object based

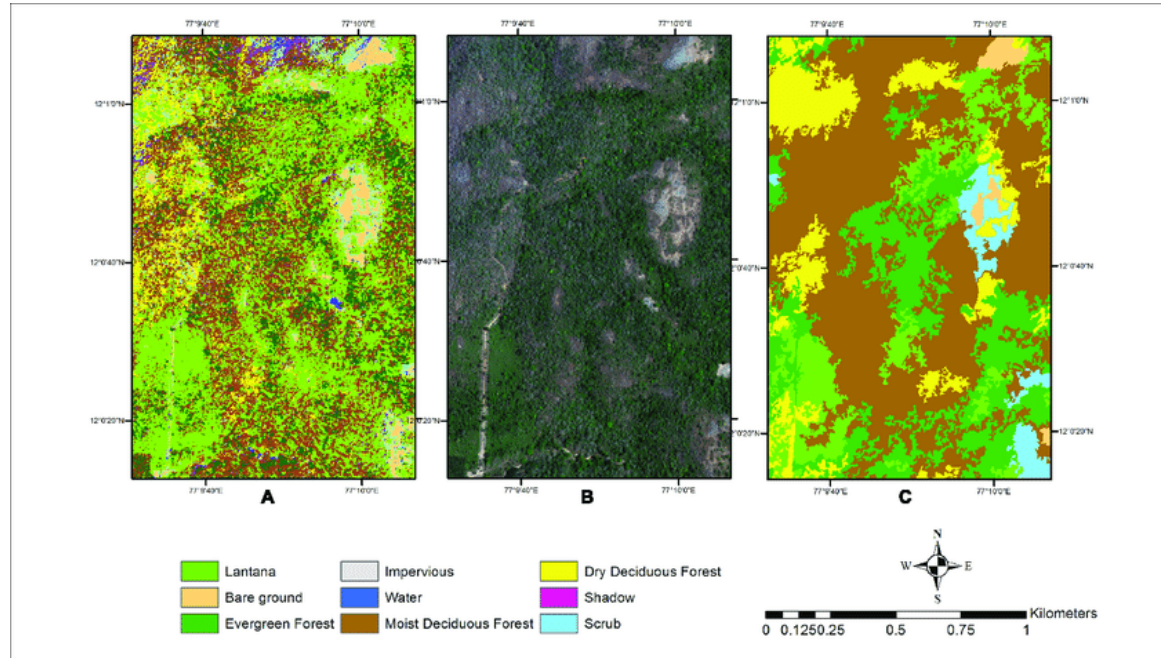


Image Recognition



Image Segmentation



Object Detection



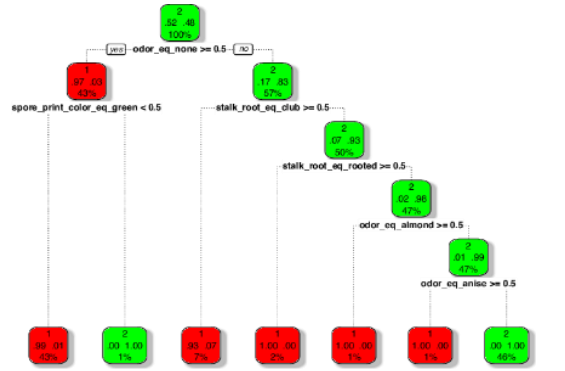
Instance Segmentation



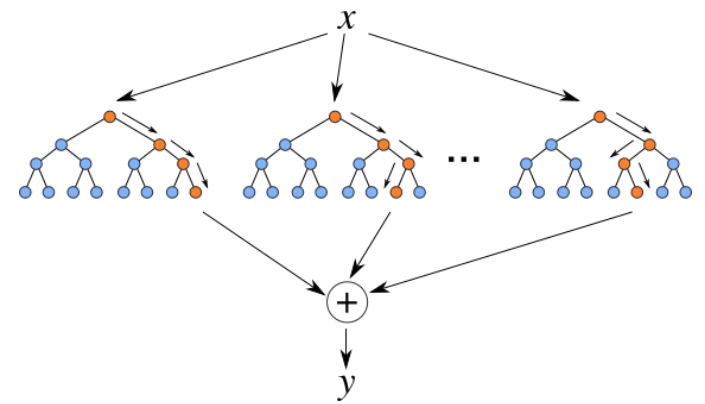
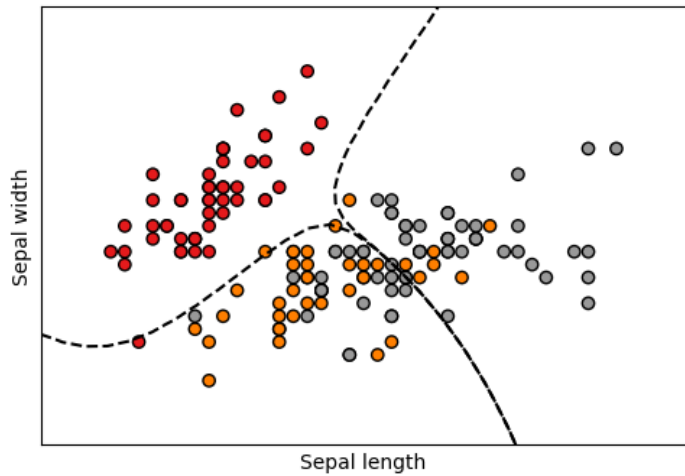
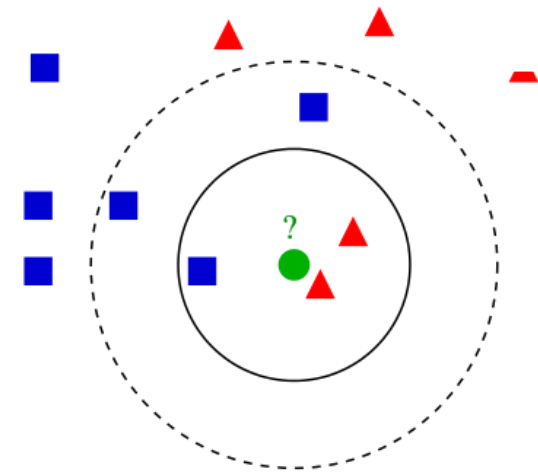
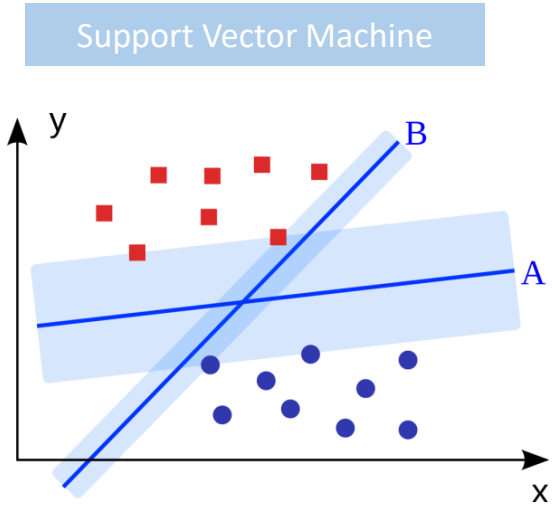


**Machine Learning  
and  
Deep Learning**

**Algorithm  
architectures**



CART Decision Tree

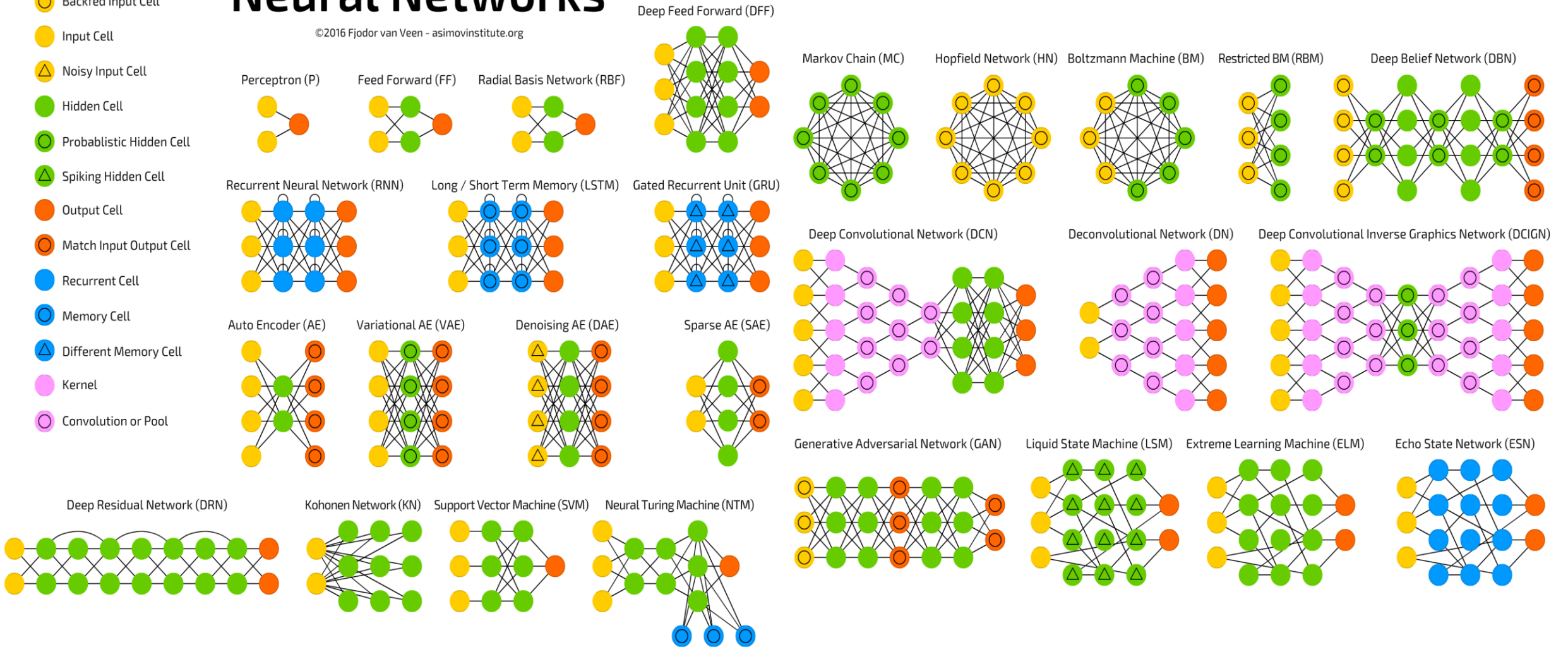


A mostly complete chart of

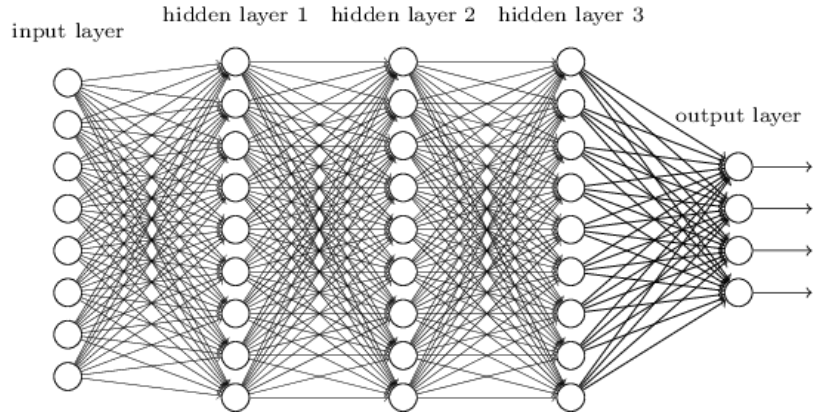
# Neural Networks

©2016 Fjodor van Veen - asimovinstitute.org

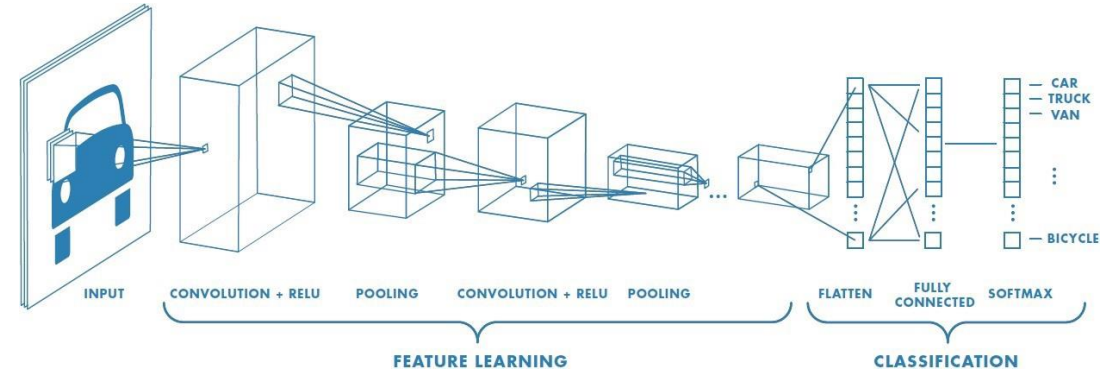
- Backfed Input Cell
- Input Cell
- Noisy Input Cell
- Hidden Cell
- Probablistic Hidden Cell
- Spiking Hidden Cell
- Output Cell
- Match Input Output Cell
- Recurrent Cell
- Memory Cell
- Different Memory Cell
- Kernel
- Convolution or Pool



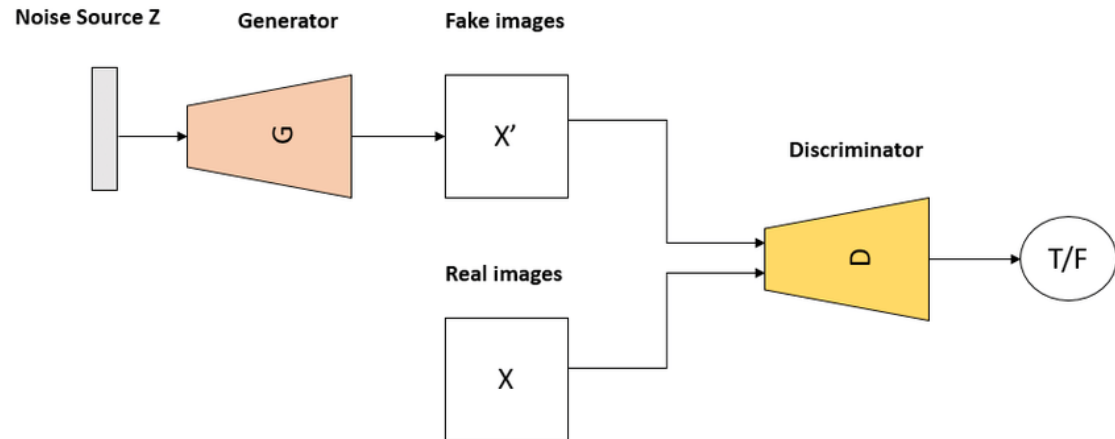
## Multi Layer Perceptron



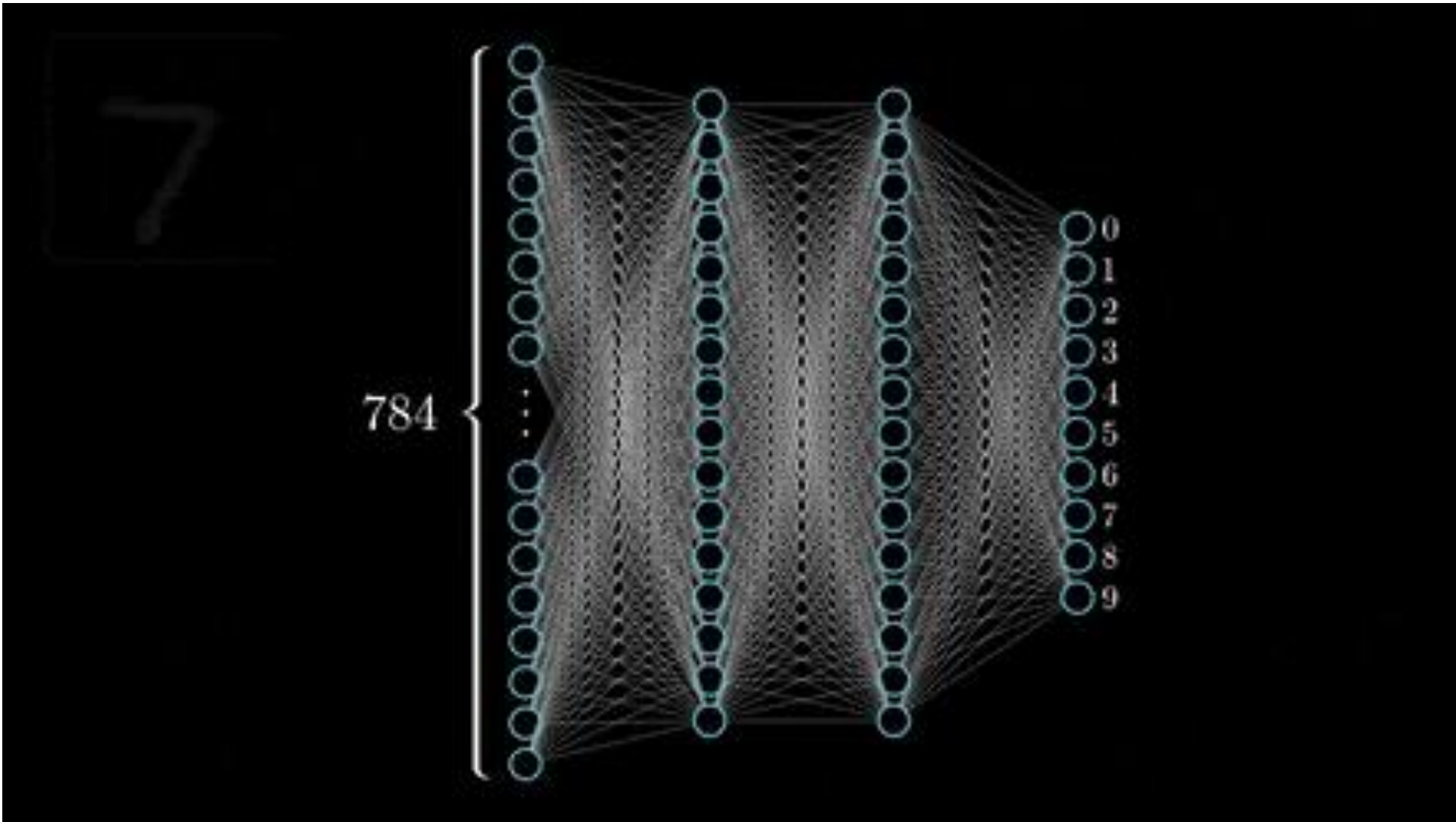
## Convolutional NN



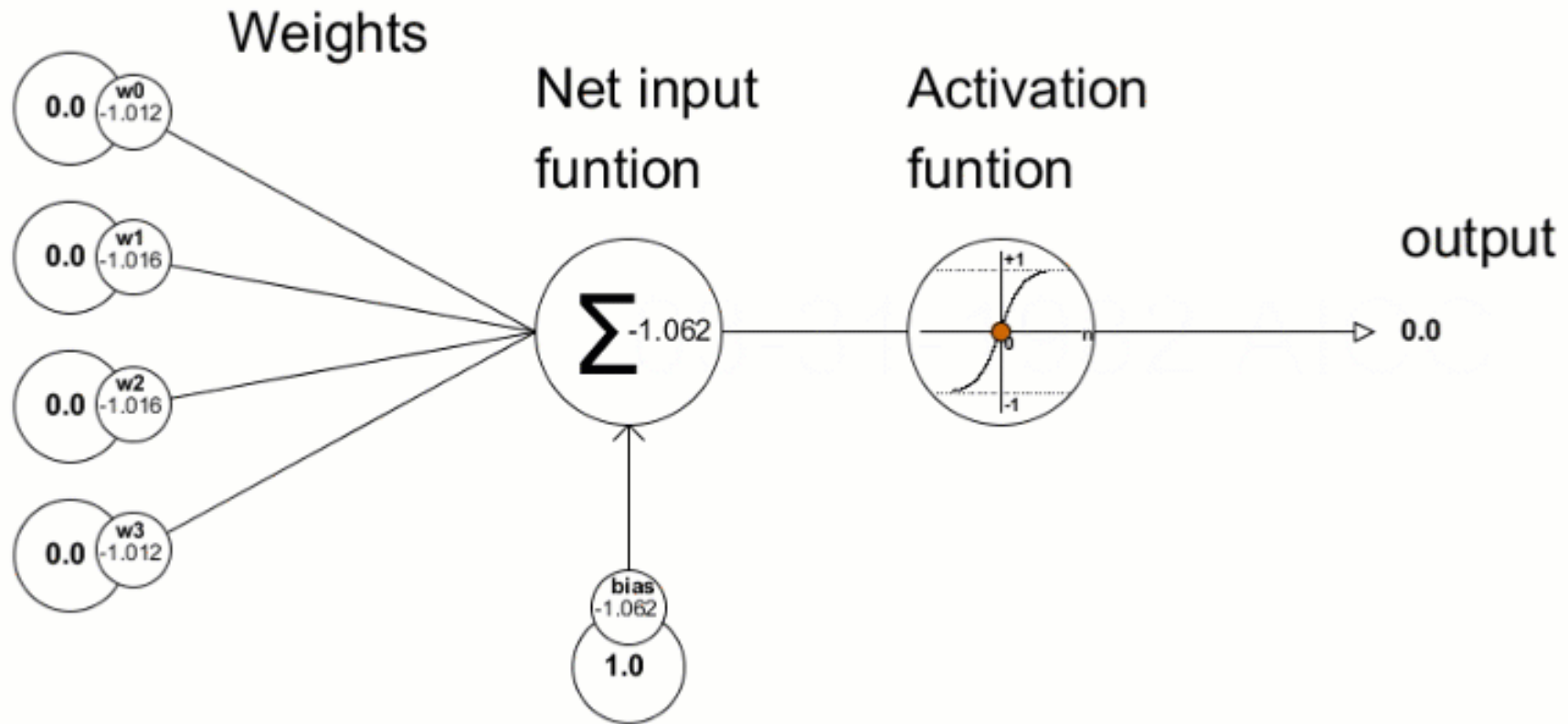
## Generative Adversarial NNs

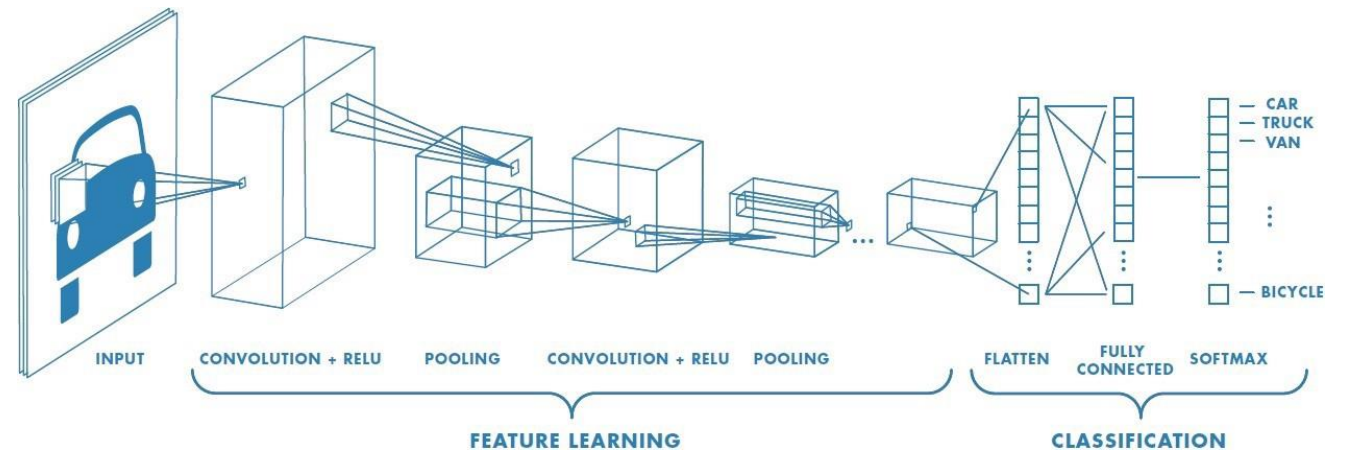
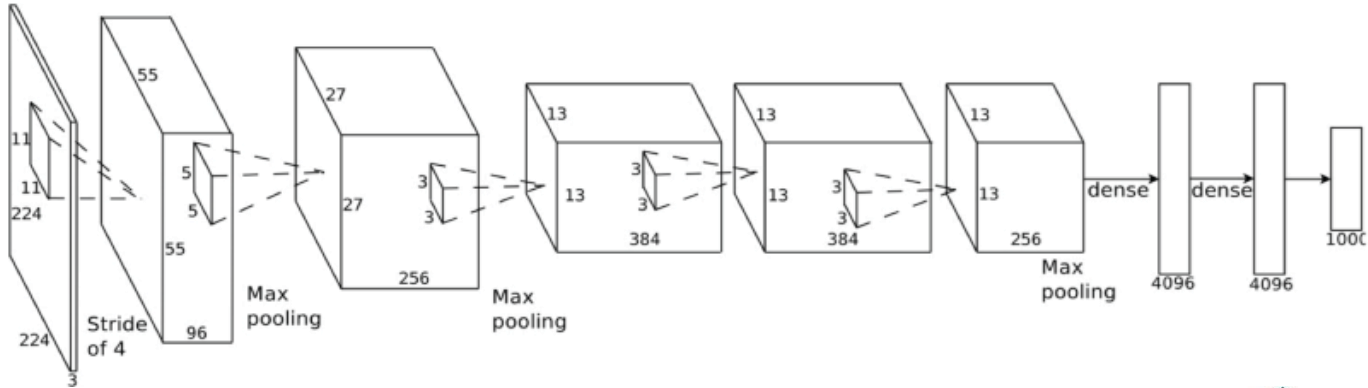
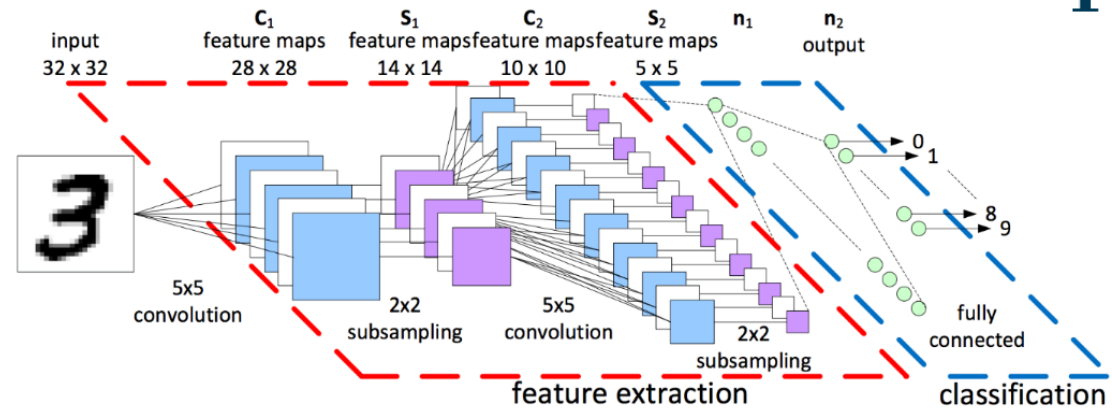






Inputs





0	0	0	0	0	0	...
0	156	155	156	158	158	...
0	153	154	157	159	159	...
0	149	151	155	158	159	...
0	146	146	149	153	158	...
0	145	143	143	148	158	...
...	...	...	...	...	...	...

Input Channel #1 (Red)

0	0	0	0	0	0	...
0	167	166	167	169	169	...
0	164	165	168	170	170	...
0	160	162	166	169	170	...
0	156	156	159	163	168	...
0	155	153	153	158	168	...
...	...	...	...	...	...	...

Input Channel #2 (Green)

0	0	0	0	0	0	...
0	163	162	163	165	165	...
0	160	161	164	166	166	...
0	156	158	162	165	166	...
0	155	155	158	162	167	...
0	154	152	152	157	167	...
...	...	...	...	...	...	...

Input Channel #3 (Blue)

-1	-1	1
0	1	-1
0	1	1

Kernel Channel #1

1	0	0
1	-1	-1
1	0	-1

Kernel Channel #2

0	1	1
0	1	0
1	-1	1

Kernel Channel #3

308

+

-498

+

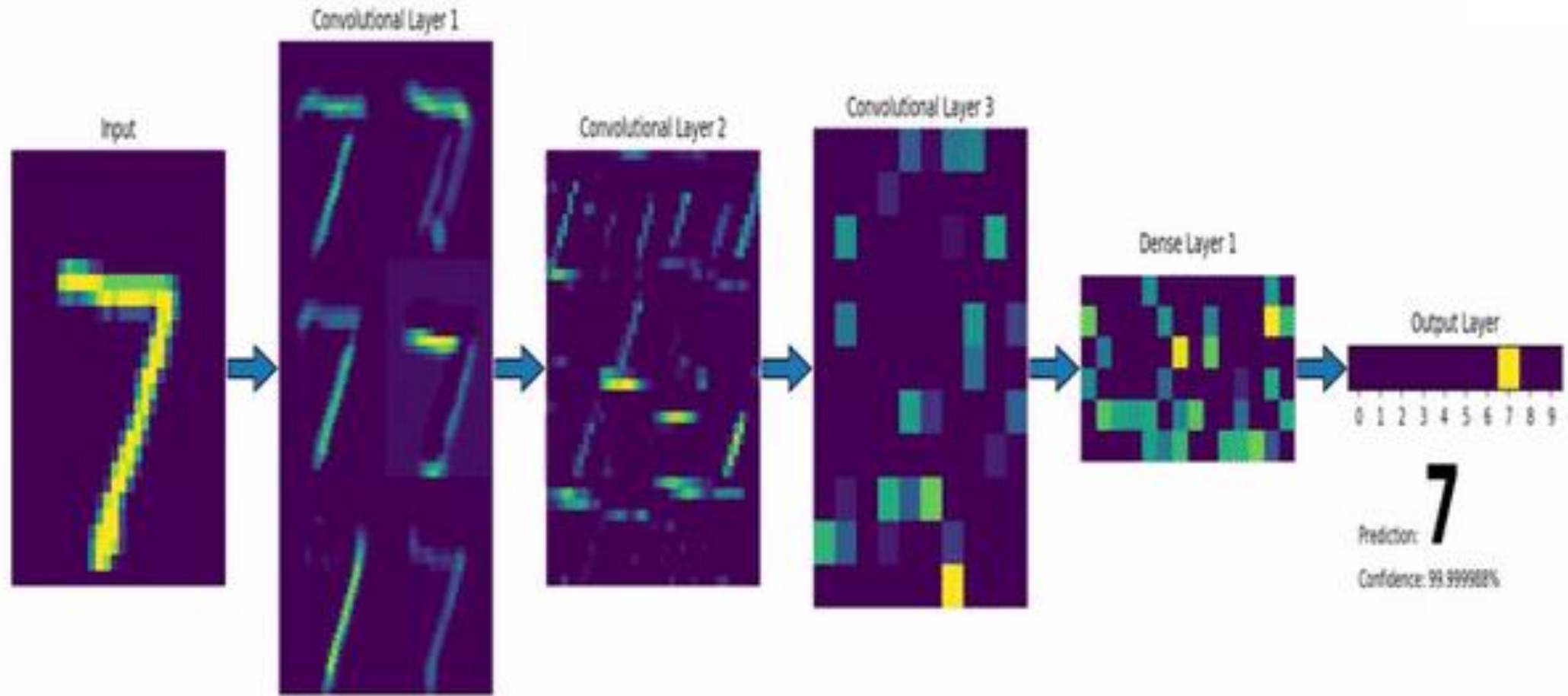
164

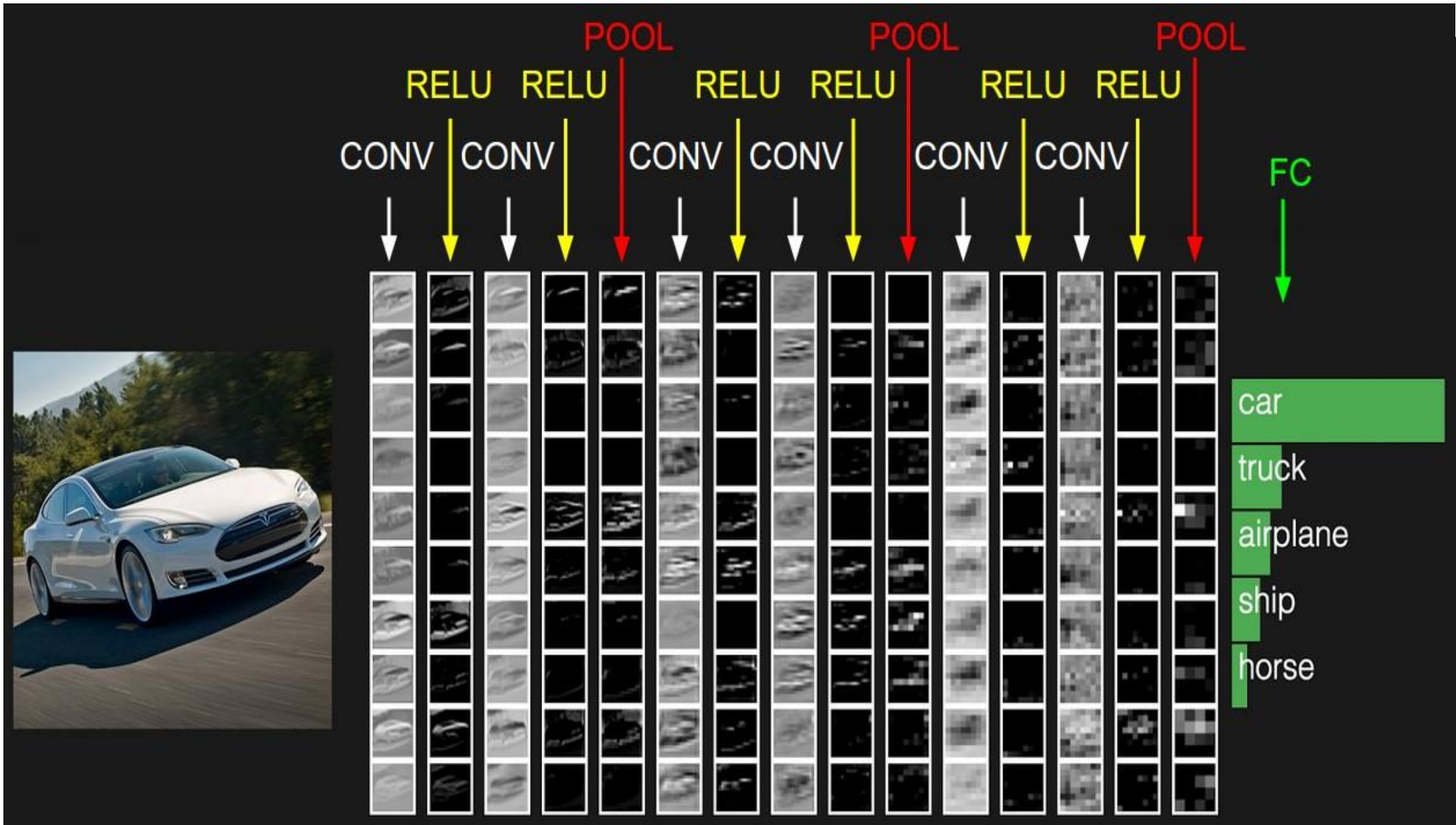
+ 1 = -25

Bias = 1

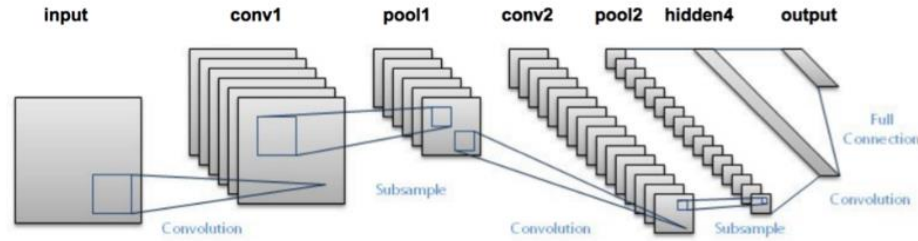
Output

-25				...
				...
				...
				...
...	...	...	...	...

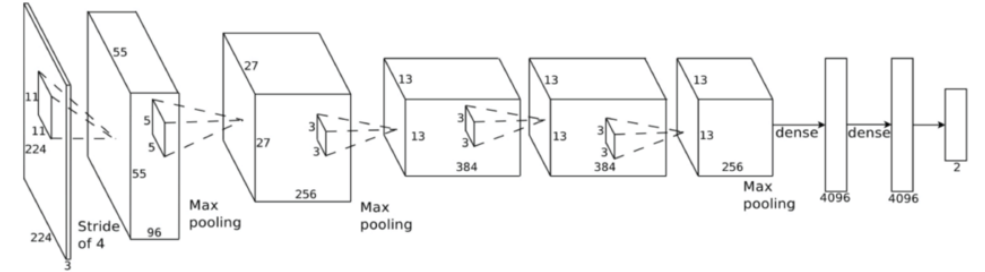




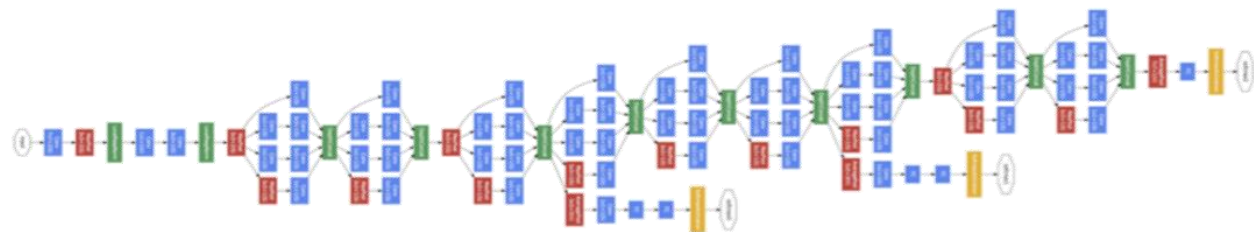
## LeNet-5 (1998)



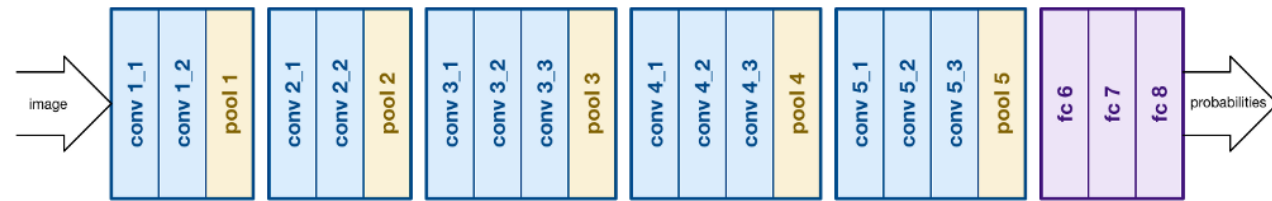
## AlexNet (2012)



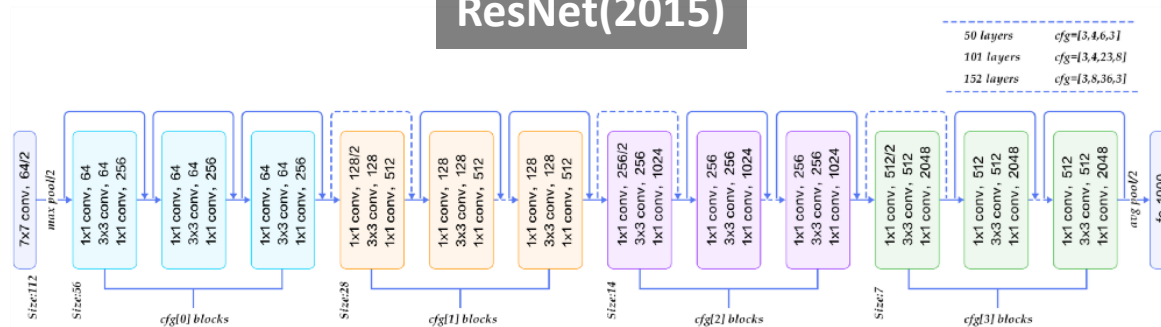
## GoogleNet/Inception(2014)

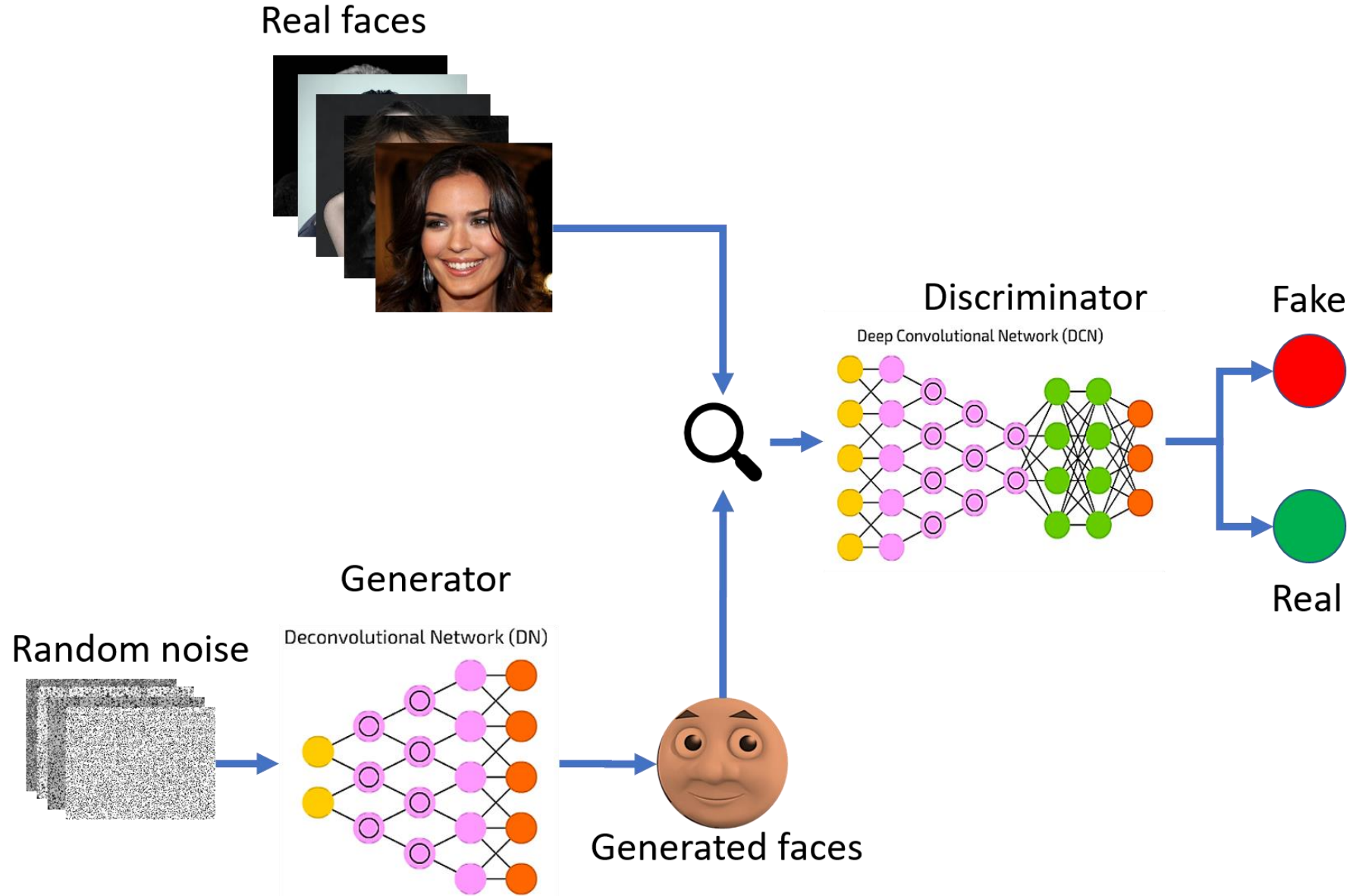


## VGGNet (2014)



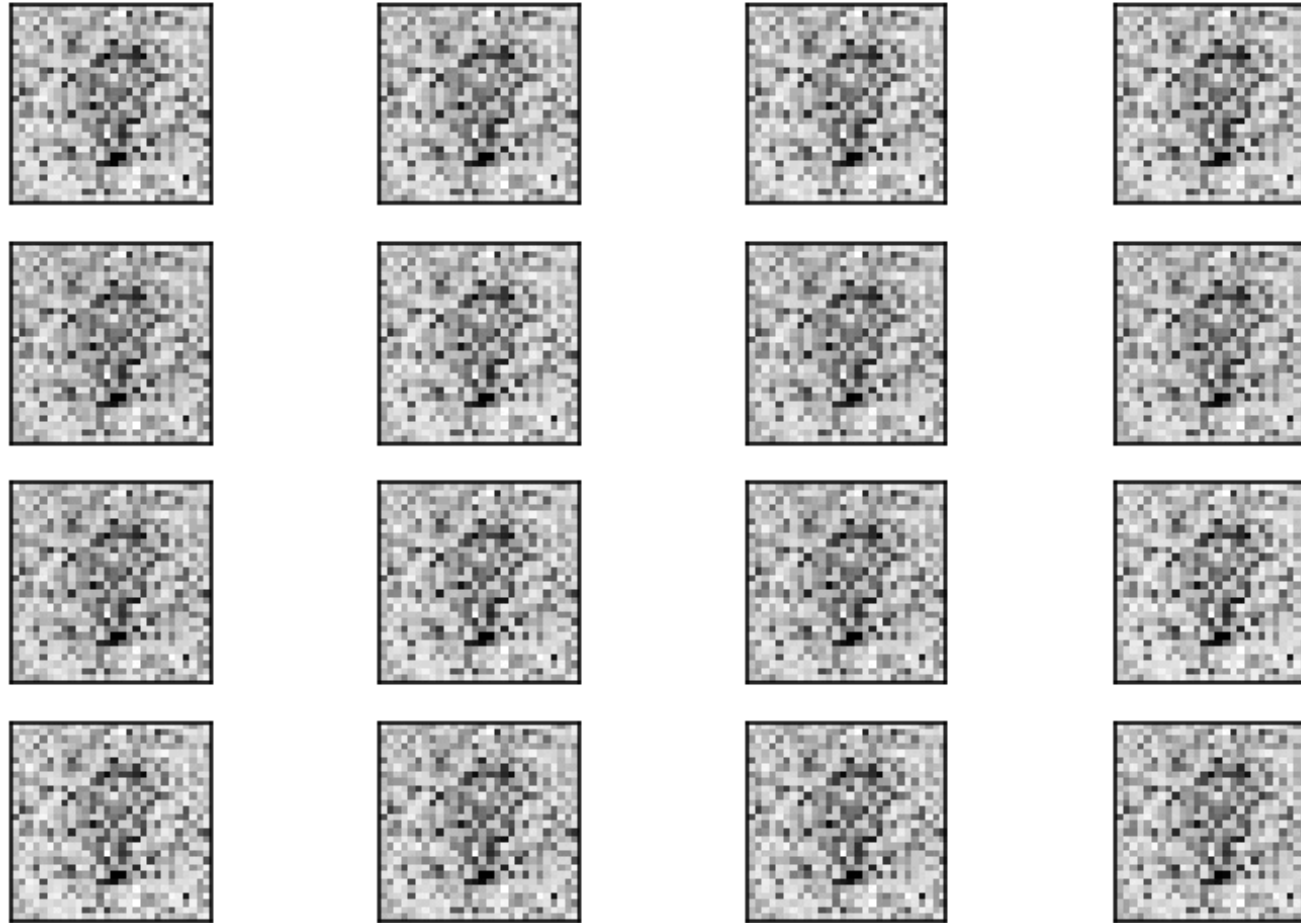
## ResNet(2015)







After 1 epoch(s)





# Machine Learning and Deep Learning

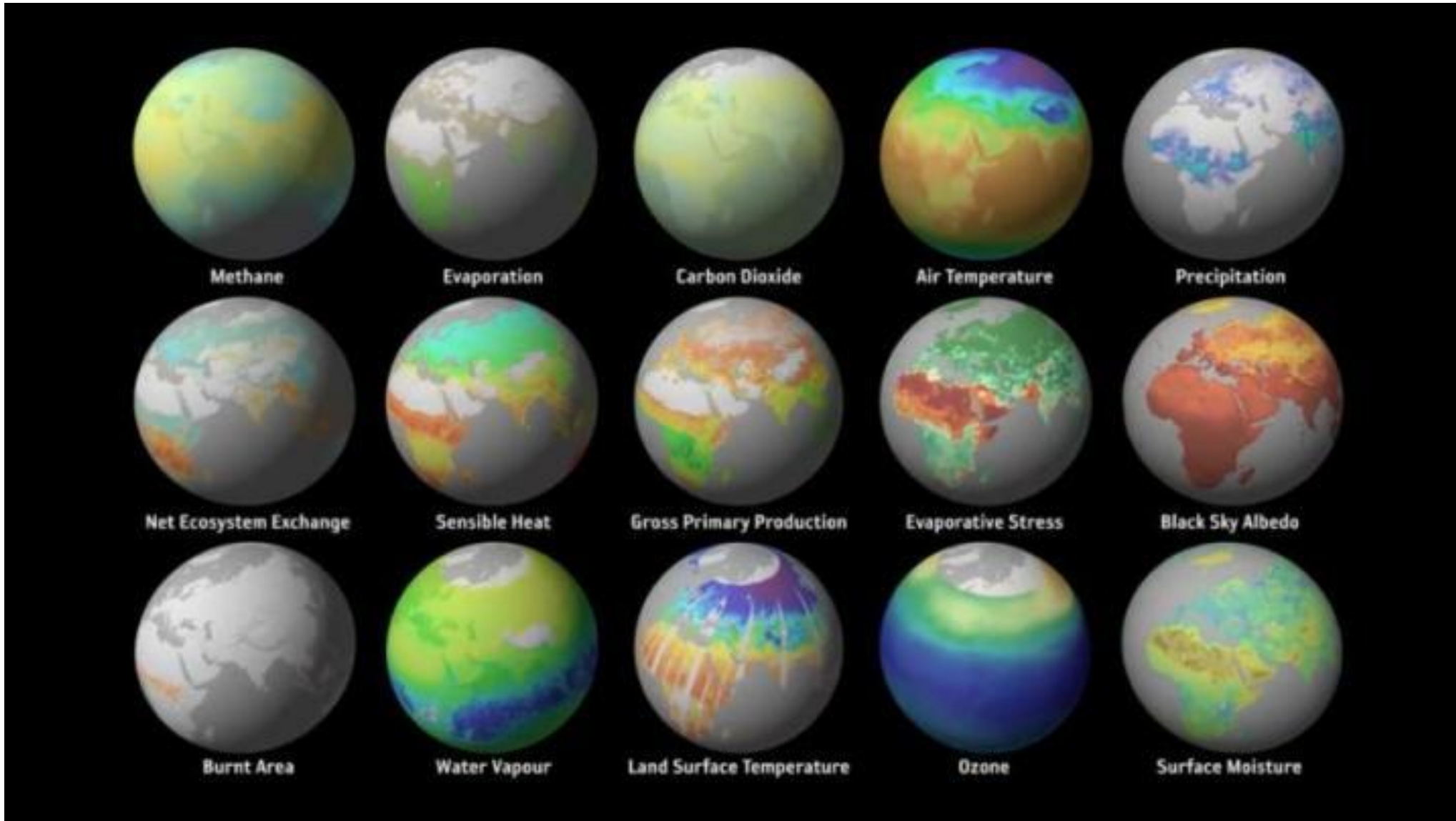
## EO DATA

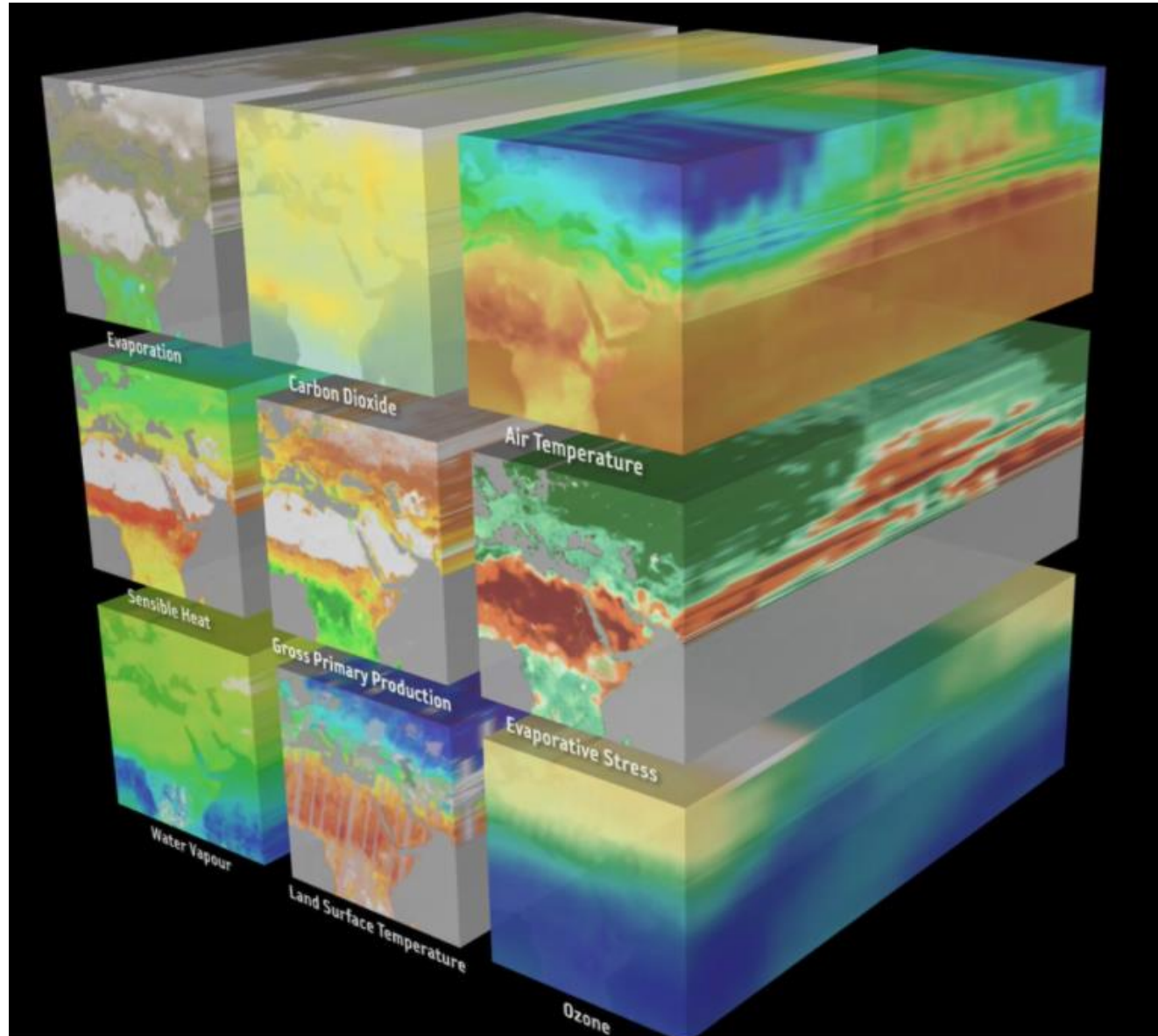


FULL, FREE AND OPEN  
ACCESS TO DATA

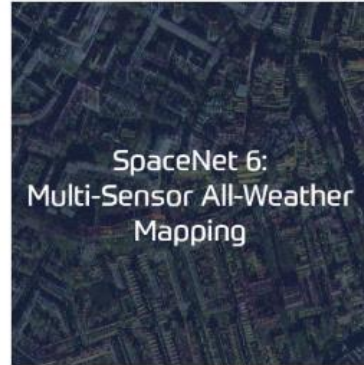
- ATMOSPHERE MONITORING
- MARINE ENVIRONMENT MONITORING
- LAND MONITORING
- CLIMATE CHANGE
- EMERGENCY MANAGEMENT
- SECURITY

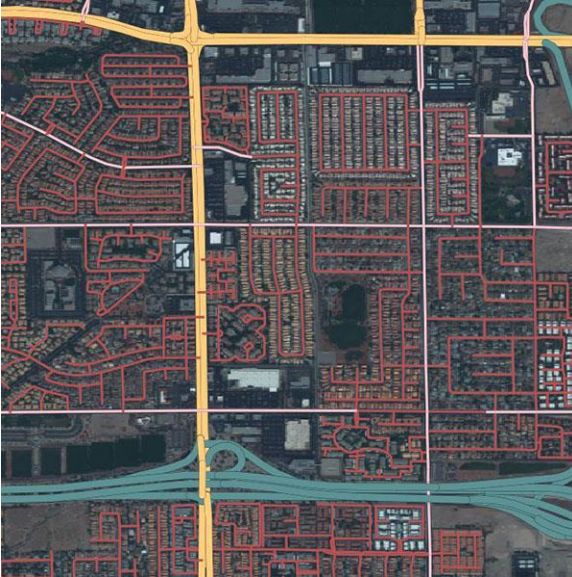
**Copernicus**  
Europe's eyes on Earth





## SpaceNet Challenge Datasets

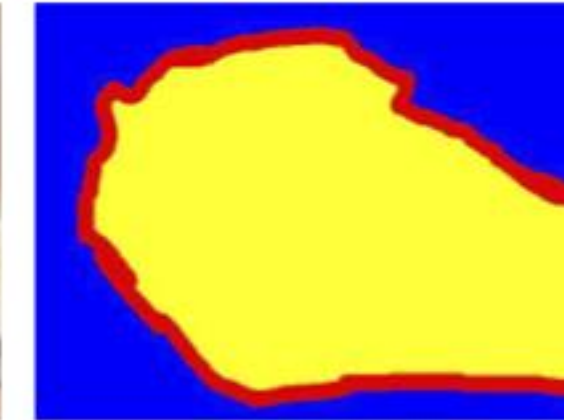
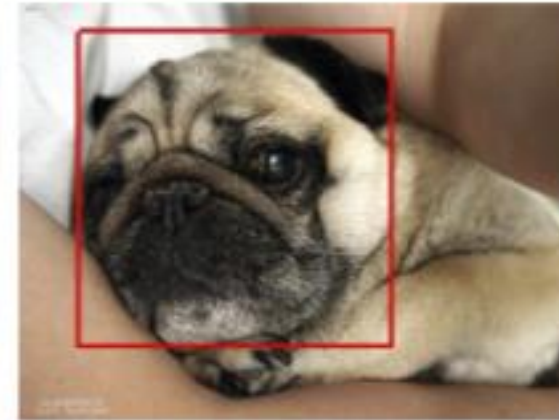






Dataset	Task	Topic	Platform	Sensor	Resolution	Example Application by Architectures
NWPU RESISC45 [155]	IR	LULC	multiple platforms	optical	high	VGG-16 [155]
EuroSAT [156]	IR	LULC	Sentinel 2	multispectral	medium	Inception-V1 and ResNet-50 [156]
BigEarthNet [116,117]	IR	LULC	Sentinel 2	multispectral	medium	ResNet-50 [117]
So2Sat LCZ42 [157]	IR	local climate zones	Sentinel 1+2	mltspectr+SAR	medium	ResNeXt-29 + CBAM [157]
SpaceNet1 [158]	IS	building footprints	-	multispectral	low	VGG-16 + MNC [158,159]
SpaceNet2 [160]	IS	building footprints	WorldView3	multispectral	high	U-Net (modified: inputdepth = 13) [160]
SpaceNet3 [161]	IS	road network	WorldView3	multispectral	high	ResNet-34 + U-Net [161]
SpaceNet4 [162]	IS	building footprints	WorldView2	multispectral	high	SE-ResNeXt-50/101 + U-Net [162]
SpaceNet5 [163]	IS	road network	WorldView3	multispectral	high	ResNet-50 + U-Net [164], SE-ResNeXt-50 + U-Net [163]
SpaceNet6 [165,166]	IS	building footprints	WorldView2 + Capella36	mltspectr + SAR	high	VGG-16 + U-Net [166]
ISPRS 2D Sem. Lab. [126]	IS	multiple classes	plane	multispectral	very high	U-Net, DeepLabV3+, PSPNet, LANet (patch attention module) [167], MobileNetV2(with atrous conv) + Dual path encoder + SE modules [168]
DeepGlobe-Road [169]	IS	road network	WorldView3	multispectral	high	D-LinkNet (ResNet-34 + U-Net with atrous decoder) [170], ResNet-34 + U-Net [171]
DeepGlobe-Building [169]	IS	building footprints	WorldView3	multispectral	high	ResNet-18 + Multitask U-Net [172], WideResNet-38 + U-Net [173]
DeepGlobe-LCC [169]	IS	LULC	WorldView3	multispectral	high	Dense Fusion Classmate Network (DenseNet + FCN varaint) [174], Deep Aggregation Net (ResNet + DeepLabV3 + variant) [175]
WHU Building [176]	IS	building footprints	multiple platforms	optical	high	VGG-16 + ASPP + FCN [177]
INRIA [178]	IS	building footprints	multiple platforms	multispectral	very high	ResNet-50 + SegNet variant [179], U-Net variant [180]
DLR-SkyScapes [181]	IS	multiple classes	helicopter	optical	very high	SkyScapesNet (custom design [181])
NWPU VHR-10 [182]	OD	multiple classes	airborne platforms	optical	very high	DarkNet + YOLO (modified: VaryBlock) [183], ResNet-101 + FPN (modified: Densely connected top-down path) + fully convolutional detector head [184]
COWC [185]	OD	vehicle detection	airborne platforms	optical	very high	VGG16 + SSD + correlation alignment domain adaptation [186]
CARPK [187]	OD	vehicle detection	drone	optical	very high	VGG16 + LPN (Layout Proposal Net) [187]
DLR 3K Munich [188]	OD	vehicle detection	airborne platform	optical	very high	ShuffleDet (ShuffleNet + modified SSD) [189]
DOTA [100]	OD	multiple classes	airborne platforms	optical	very high to high	ResNet-50+improved Cascade R2CNN see leader board of [100], ResNet-101/FPN + Fater R-CNN OBB + RoI transformer [138]
DIOR [24]	OD	multiple classes	multiple platforms	optical	heigh to medium	ResNet-101 + PAnet and ResNet-101 + RetinaNet [24]

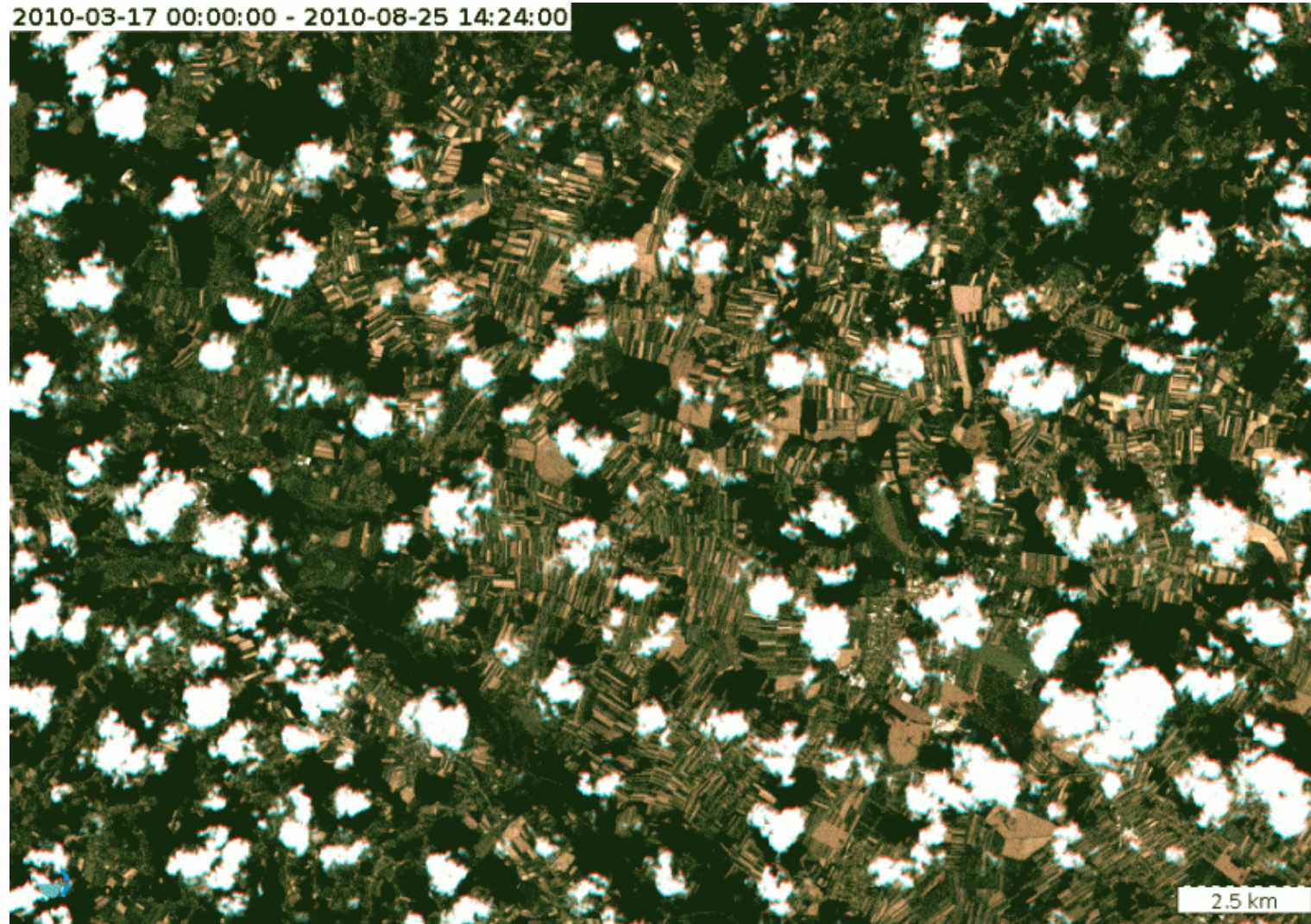
## Satellite Images (NO DOGS NO CATS)



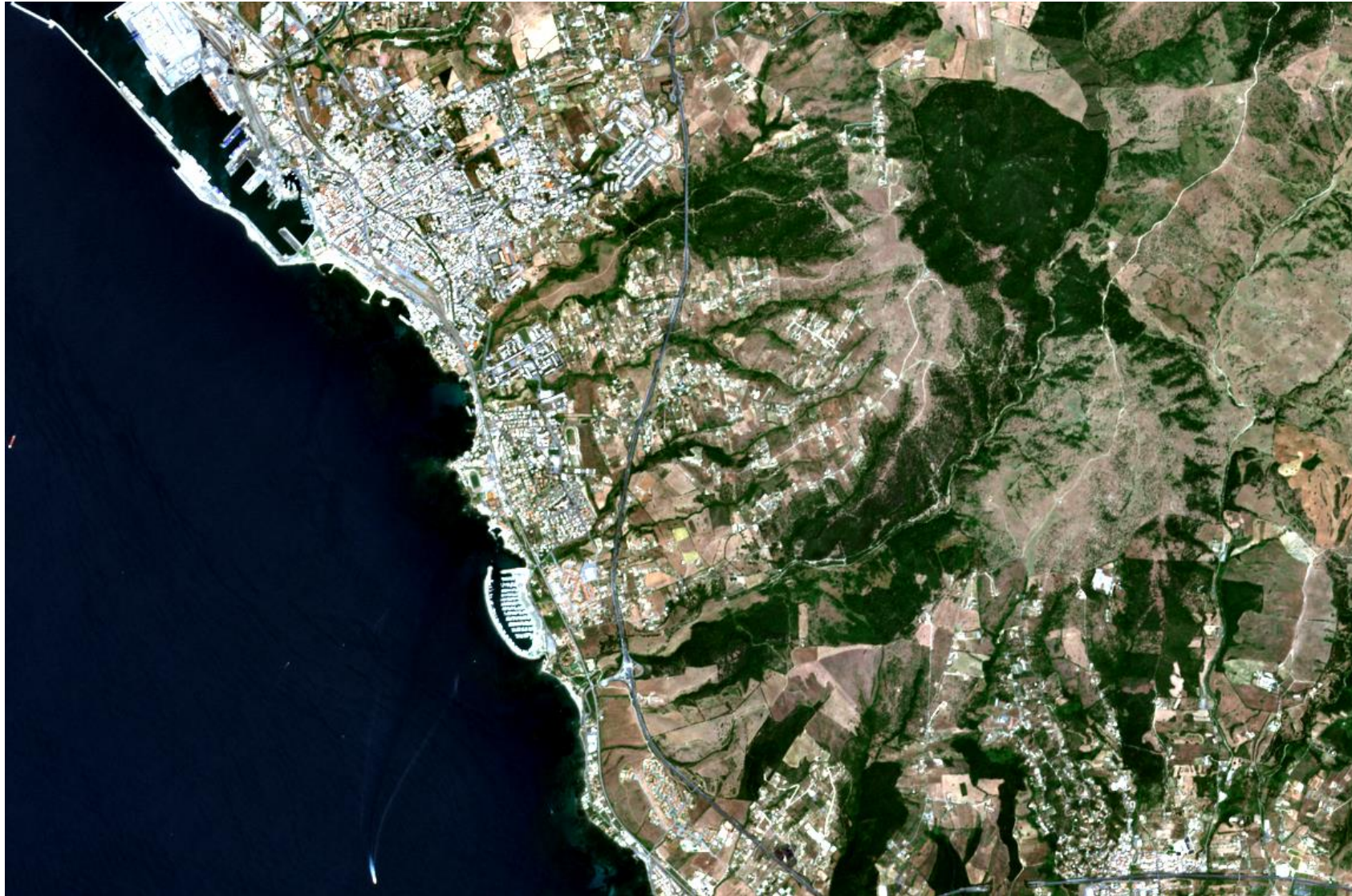
## Satellite Images (SHADOWS and OFF-NADIR angles)



## Satellite Images (CLOUDS)



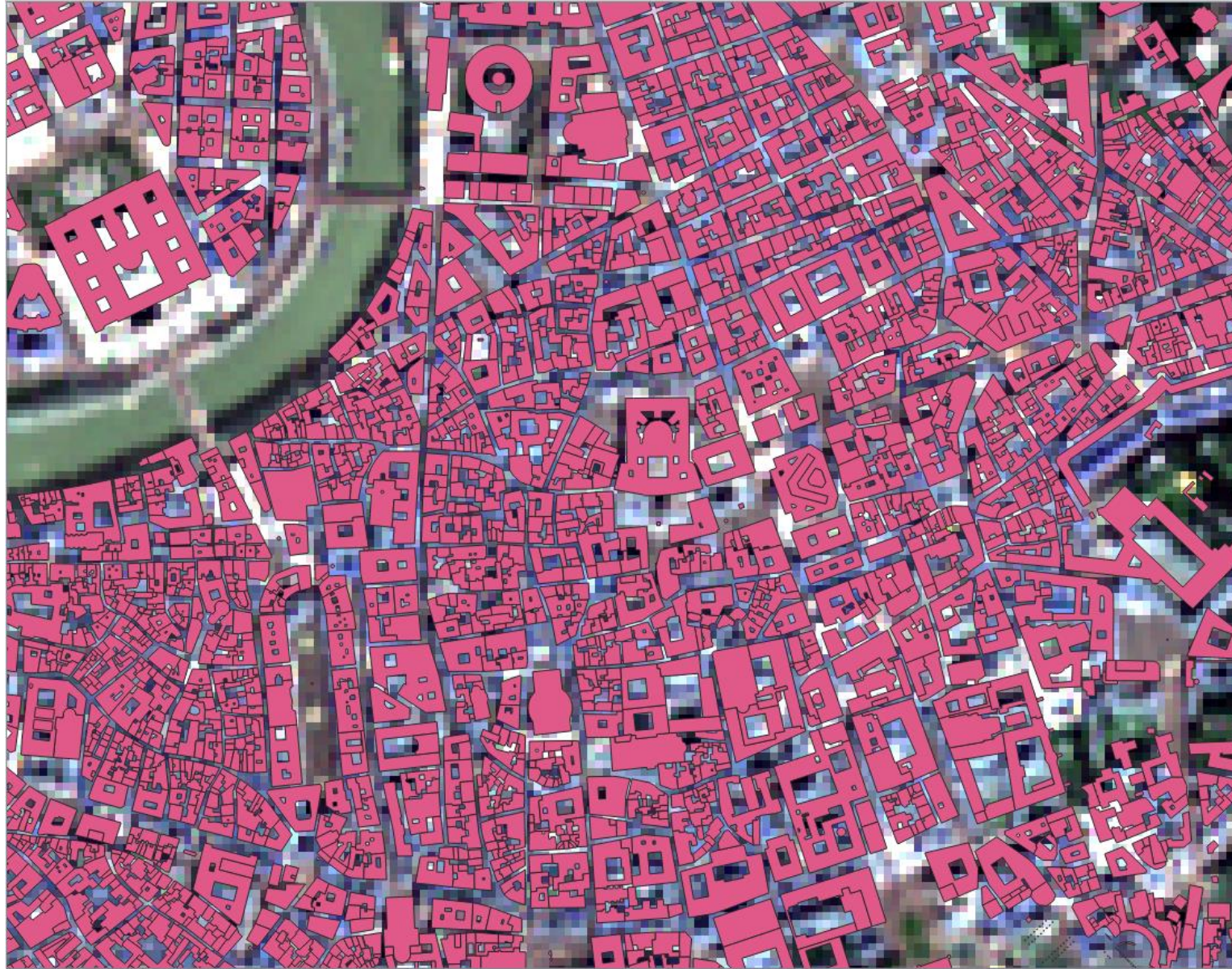
## Satellite Images (PIXEL RESOLUTION)



## Satellite Images (PIXEL RESOLUTION)



## Misalignment between GT and satellite images



## Time series challenges

- Coregistration
- Different light condition
- No-data interpolation







eo-learn makes extraction of valuable information from satellite imagery easy.



openEO develops an open API to connect R, Python, JavaScript and other clients to big Earth observation cloud back-ends in a simple and unified way.



Open Interoperable platform for unified access and analysis of earth observation data

## neat-EO

Efficient AI4EO OpenSource framework



COPERNICUS ACCESS  
PLATFORM INTERMEDIATE  
LAYERS SMALL SCALE  
DEMONSTRATOR



**Copernicus and Sentinel data at your fingertips** alongside cloud computing resources and tools

## Machine Learning tools & platforms landscape - v.1.0 January 2021

Presented by MLReef

### DATA MANAGEMENT

**Data Exploration & Management**

COHESITY, rubrik, allegroai, ALLUXIO, Amundsen, druid, Hudi, MLReef, databricks, ALGORITHMIA, Spark, APARAVI, ATSCALE, Amazon Redshift, CAZENA, Google Cloud, CLOUDERA, kaggle, datagrok, dataiku, ClearSky, DATERA, dremio, elastice, erwin, Excelero, Fluree, COLINI, HYCU, imply, komprise, plicaso, presto, Weights & Biases, HIVE, tamr, VEARCH, vexoto, Yellowbrick

**Data Labelling**

appen, Datarurks, doccano, iMerit, prodigy, Labelbox, SUPERVISELY, Playment, scale, snorkel, HIVE

**Data Streaming**

Frank, ALLUXIO, Hudi, kafka, CONFLUENT, VALOHAI, Strim

**Data Version Control**

databricks, dataiku, DVC, FLOYDHUB, MLReef, Pachyderm, Waterline Data, QR, allegroai

**Data Generation**

scale, scrapinghub, DATPROF

**Data Privacy**

aircloak, Celantur, mostly, PySyft, TUMULT

**Data Quality Checks**

arize, great\_expectations, Navego

### MODELLING

**Notebook / Code Management**

colab, databricks, Deepnote, DOMINO, FLOYDHUB, kaggle, MLReef, polyaxon, Pachyderm, Weights & Biases, alteryx

**Data Processing & Visualization**

alteryx, ASANO, colab, DASK, databricks, dotData, Flyte, gluent, iguazio, imply, incorta, mflow, incorta, MLReef, MODIN, Navtego, OpenML, Pachyderm, plicaso, presto, Prometheus, SSAS, snorkel, SQLFlow, Starburst, TUI, v8x, VALOHAI, allegroai, Weights & Biases

**Feature Engineering**

dotData, FEAST, Featuretools, Pachyderm, TACTON, SSAS, Weights & Biases, iguazio

**Model Training**

alteryx, iguazio, colab, databricks, DOMINO, dotScience, FLOYDHUB, Flyte, LEWIG, kaggle, MLReef, MARS, MEDVIEW, mflow, PerceptiLabs, snorkel, TUI, VALOHAI, SSAS, Anyscale, Pachyderm, OPENML

**Experiment Tracking**

iguazio, allegroai, comet, DataRobot, datmo, DOMINO, FLOYDHUB, LEWIG, mflow, MLReef, polyaxon, SPELL, VALOHAI, Weights & Biases, Losswise

**Model (Hyperparameter) Optimization**

Angel, comet, DataRobot, polyaxon, SIGOPT, SPELL, Tune, OPTUNA

**Auto ML**

DataRobot, Determined AI, dotData, Google Cloud, Keras, TransmogriAI, iguazio

**Model Management**

alteryx, ALGORITHMIA, allegroai, databricks, dataiku, Determined AI, stockship, dotData, FLOYDHUB, LUON, MLReef, modzy, mflow, PerceptiLabs, polyaxon, SSAS, TUI, VALOHAI, Verta

**Model Evaluation**

arize, MLReef, OpenML, TensorBoard

**Model Explainability**

fiddler, InterpretML, LUCID, PerceptiLabs, Shop, Verta

**Frameworks & major libraries**

Chainer, Keras, Spark MLlib, mxnet, Caffe2, PyTorch, spaCy, TensorFlow, XGBoost, ONNX, CNTK, theano, matplotlib, julia, torch

### CONTINUOUS DEPLOYMENT

**Data Flow Management**

ALLUXIO, spark, ASANO, kafka, dataiku, dotData, HYCU, PREFECT

**Feature Transformation**

FEAST, Featuretools, TACTON, iguazio, dataiku

**Monitoring**

ALGORITHMIA, arize, DataDog, DataRobot, DOMINO, iguazio, Losswise, snorkel, Unravel, VALOHAI, Verta, datatron, alteryx

**Model Compliance & Audit**

ALGORITHMIA, SSAS, Keras

**Model Deployment & Serving**

AIBLE, ALGORITHMIA, allegroai, cortex, dataiku, datatron, datmo, DOMINO, dotData, FLOYDHUB, FRITZ AI, iguazio, Kubeflow, mflow, modzy, Databricks, PRODUCER3D, SSAS, SELDON, SPELL, SERPENT, VALOHAI, Verta, Google Cloud, alteryx

**Model Validation**

arize, datatron, fiddler, LUCID, MLReef, SSAS, OpenML

**Model Compatibility**

MMdnn, ONNX, plaidML

### COMPUTING MANAGEMENT

**Computing & Data Infrastructure**

Google Cloud, CLOUDERA, ORACLE, Amazon, Linode, Microsoft, Lightbend, Databricks

**Environment Management**

CONDA, databricks, datmo, MAHOUT, MLReef, allegroai

**Resource Allocation**

ALGORITHMIA, Google Cloud, MLReef, databricks, dataiku, Determined AI, FLOYDHUB, polyaxon, SPELL, VALOHAI, allegroai

**SCALING**

argo, dataiku, DATADOG, datatron, datmo, SELDON, tvn, Keras

**SECURITY & PRIVACY**

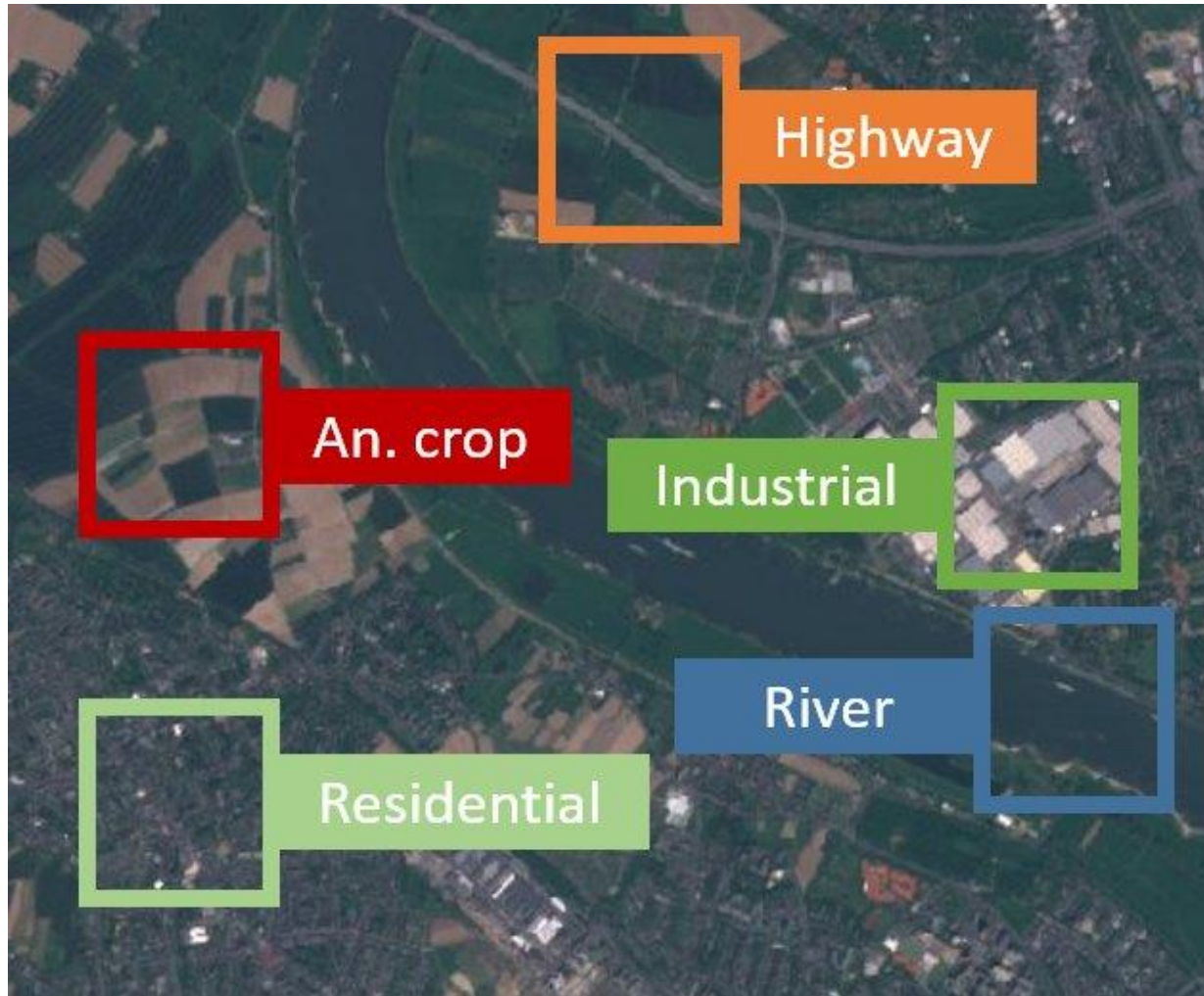
DATADOG, modzy, PySyft, TUMULT, ALGORITHMIA



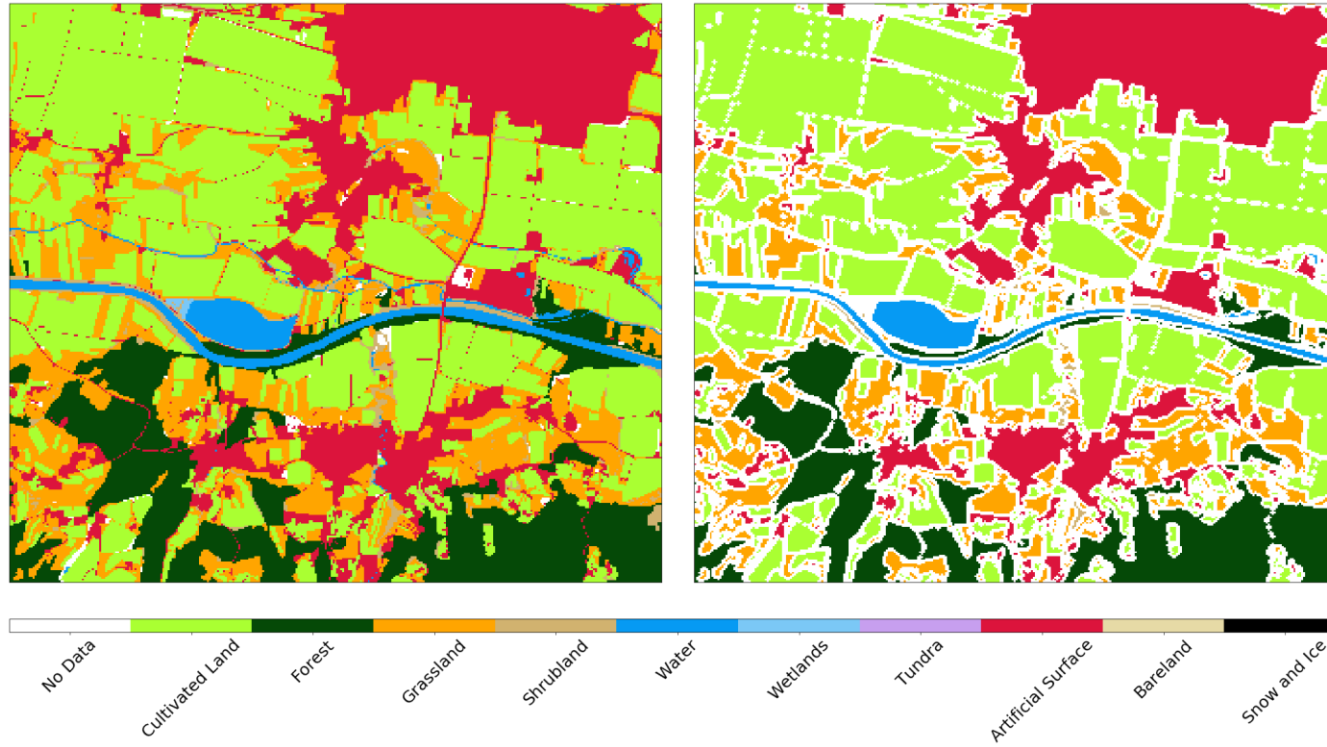
**Machine Learning  
and  
Deep Learning  
EO Applications**



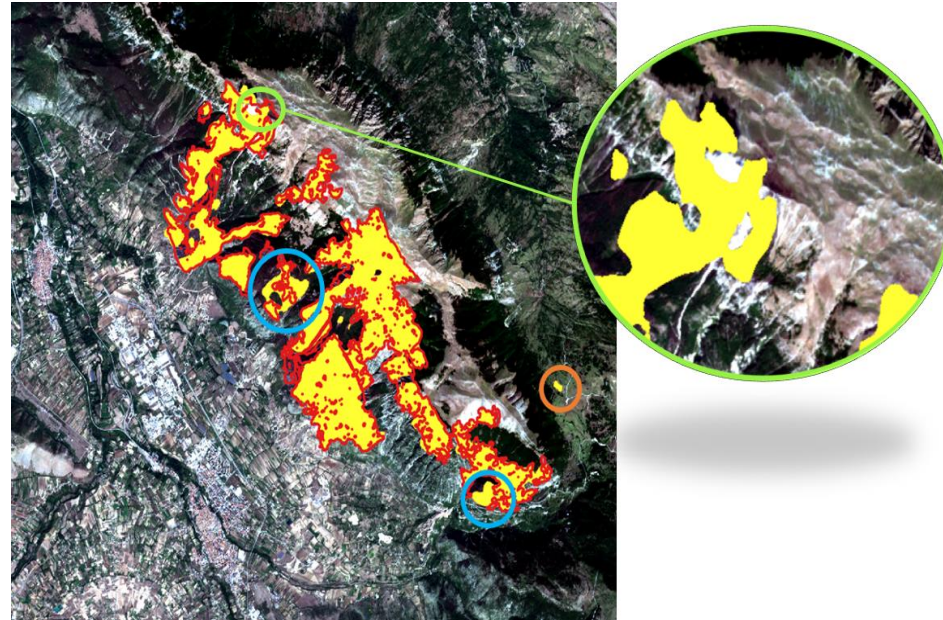
<b>Topic:</b>	<b>Object Detection</b>
<b>Sensor:</b>	<b>Optical -WV3</b>
<b>Resolution:</b>	<b>VHR-0.5m</b>
<b>Bands:</b>	<b>RGB</b>
<b>Training:</b>	<b>SpaceNet</b>
<b>Method:</b>	<b>MaskRCNN</b>



<b>Topic:</b>	<b>LULC (tile based)</b>
<b>Sensor:</b>	<b>multispectral-S2</b>
<b>Resolution:</b>	<b>medium-10m</b>
<b>Bands:</b>	<b>13</b>
<b>Training:</b>	<b>EuroSAT</b>
<b>Method:</b>	<b>ResNet-50</b>



<b>Topic:</b>	LCLU (pixel based)
<b>Sensor:</b>	multispectral - S2 TS
<b>Resolution:</b>	medium - 10m
<b>Training:</b>	provided by government
<b>Method:</b>	LGBM-UNet



<b>Topic:</b>	uns. Change detection
<b>Sensor:</b>	multispectral - S2 pre-post
<b>Resolution:</b>	medium - 10m
<b>Bands:</b>	12
<b>Method:</b>	Autoencoder

# Change detection



ML+DL



**Topic:** uns/sup Change detection  
**Sensor:** multispectral - S2 TS and pre-post  
**Resolution:** medium - 10m  
**Bands:** 12  
**Bands:** Onera Satellite Change Detection  
**Method:** RF + change point det + Unet





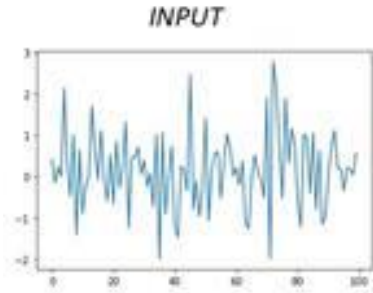
17 May 2019

5 April 2018

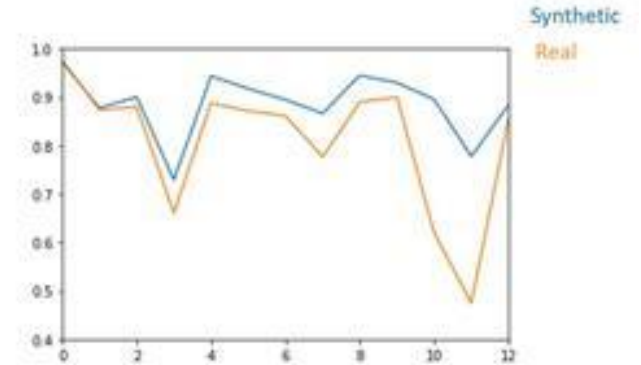
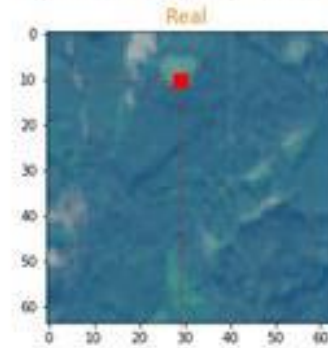
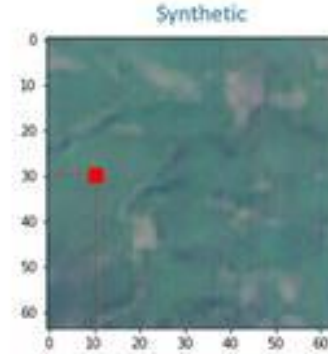
**ONE  
ATLAS**

**AIRBUS**

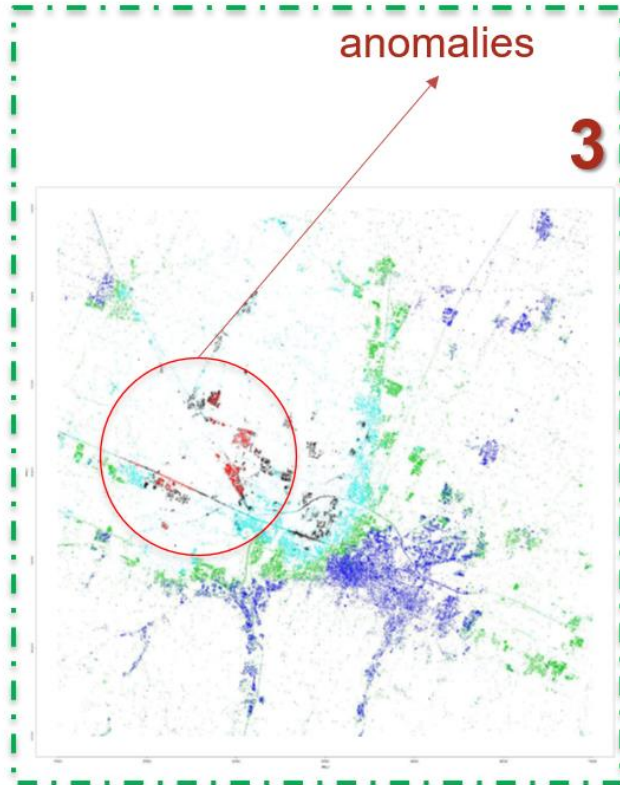
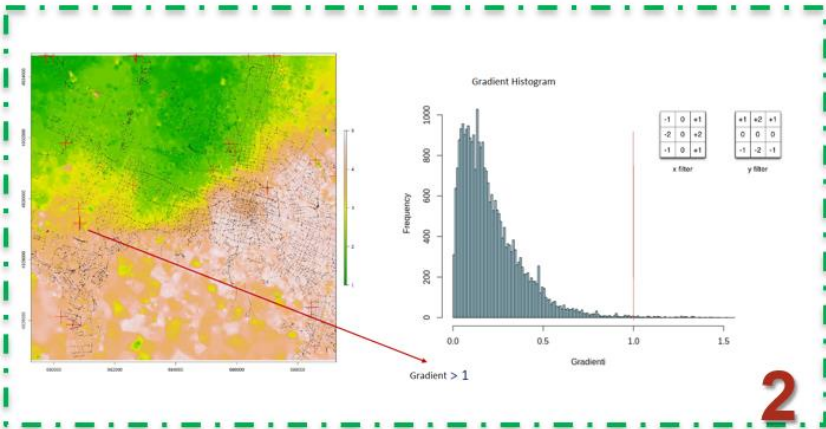
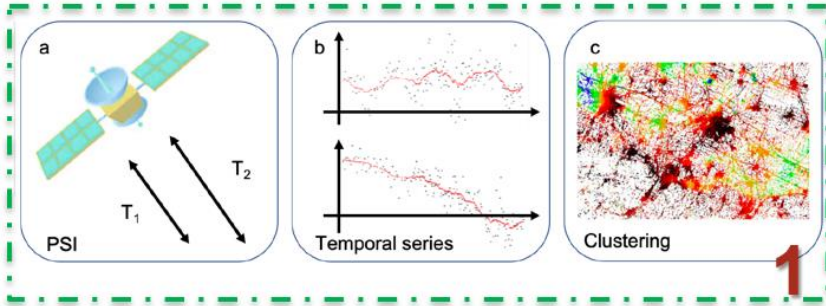
<b>Topic:</b>	sup. Change Detection
<b>Data:</b>	VHR - Pléiades - SPOT
<b>Method</b>	: Machine Learning + human check



GAN



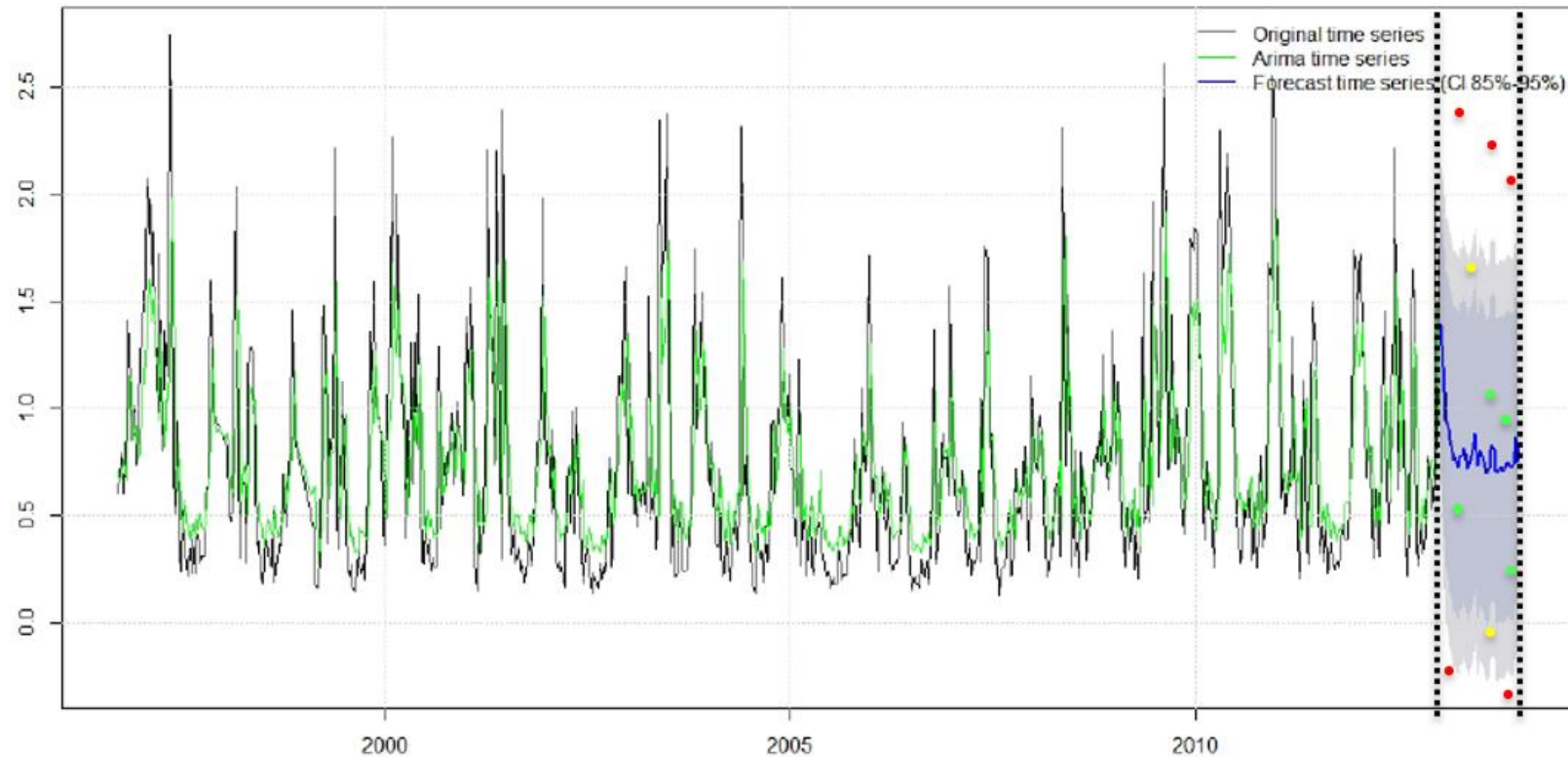
**Topic:** Data Augmentation  
**Sensor:** multispectral - S2  
**Resolution:** medium - 10m  
**Bands:** 12  
**Training:** EuroSAT  
**Method:** GANs



<b>Topic:</b>	<b>Clustering PS</b>
<b>Data:</b>	<b>PS from S1</b>
<b>PS Num:</b>	<b>~10M</b>
<b>Clusters:</b>	<b>5</b>
<b>Method:</b>	<b>K-Means</b>

## MDPI and ACS Style

Amoroso, N.; Cilli, R.; Bellantuono, L.; Massimi, V.; Monaco, A.; Nitti, D.O.; Nutricato, R.; Samarelli, S.; Taggio, N.; Tangaro, S.; Tateo, A.; Guerriero, L.; Bellotti, R. PSI Clustering for the Assessment of Underground Infrastructure Deterioration. *Remote Sens.* **2020**, *12*, 3681.



<b>Topic:</b>	<b>Anomaly detection</b>
<b>Data:</b>	<b>Marine data</b>
<b>Rate:</b>	<b>Weekly</b>
<b>Method:</b>	<b>LSTM+ARIMA</b>

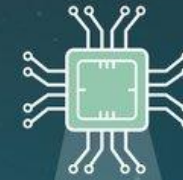
## FSSCat/ $\Phi$ -sat-1

Demonstrating the potential of AI for Earth observation



$\Phi$ -sat-1 is a new artificial intelligence experiment carried on the Federated Satellite Systems (FSSCat) mission

#FSSCat #Phisat1



$\Phi$ -sat-1 technology processes data on board



Detecting clouds in the images



Eliminating images with too much cloud cover



Returning only usable data to Earth



**CRITE:**  
AI to map  
shadowed coffee  
plantations using  
multi-temporal  
and multi-sensor  
EO images

## **CRITE - Project**