ENPC Data Science Week

Deep Learning for Remote Sensing

Alexandre Boulch

ONERA

THE FRENCH AEROSPACE LAB

retour sur innovation

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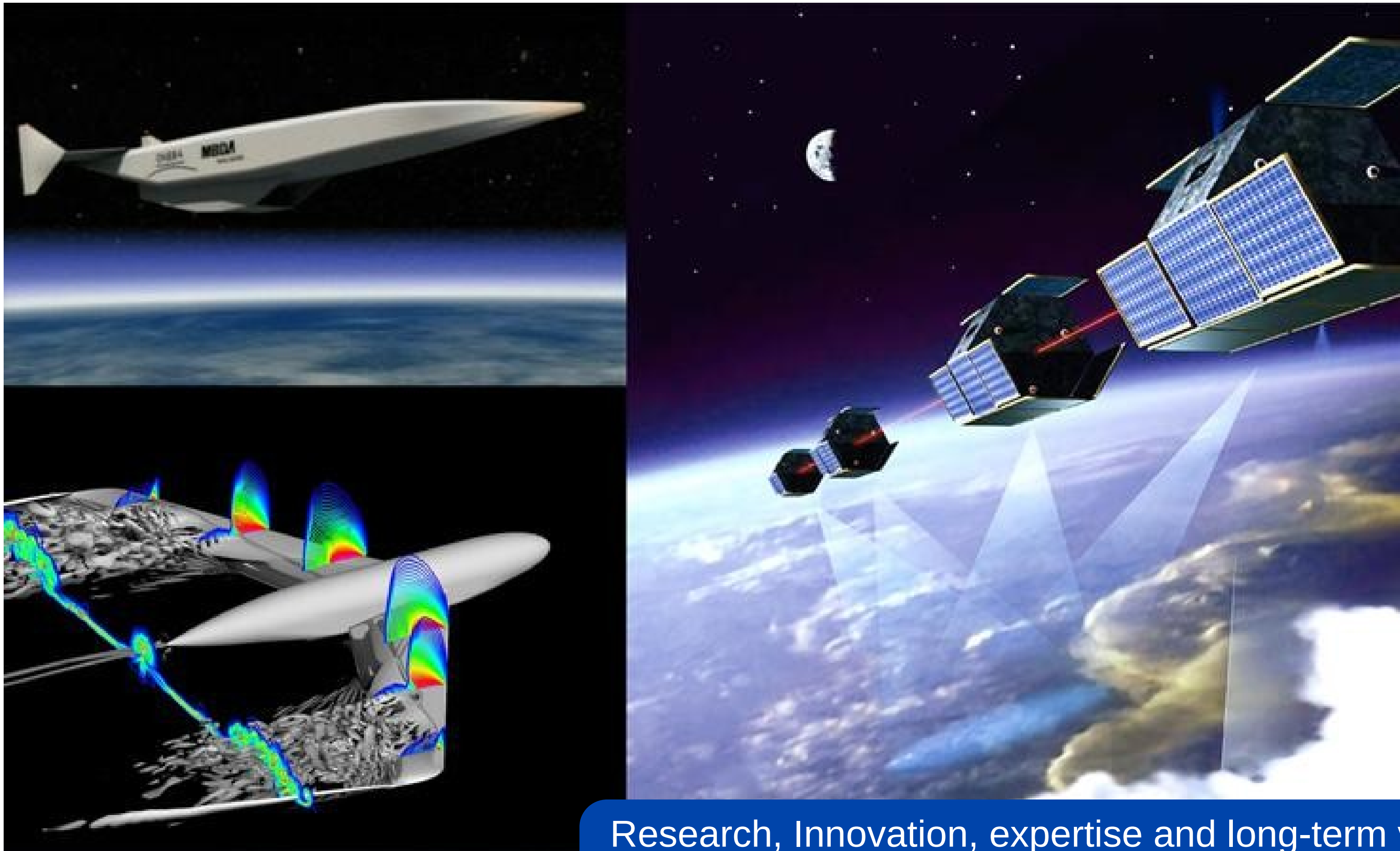


Research, Innovation, expertise and long-term vision for industry, French government and Europe

Materials

Propulsion

Optics

Electromagnetism

Aerodynamics

Information Processing

Flight dynamics

Materials

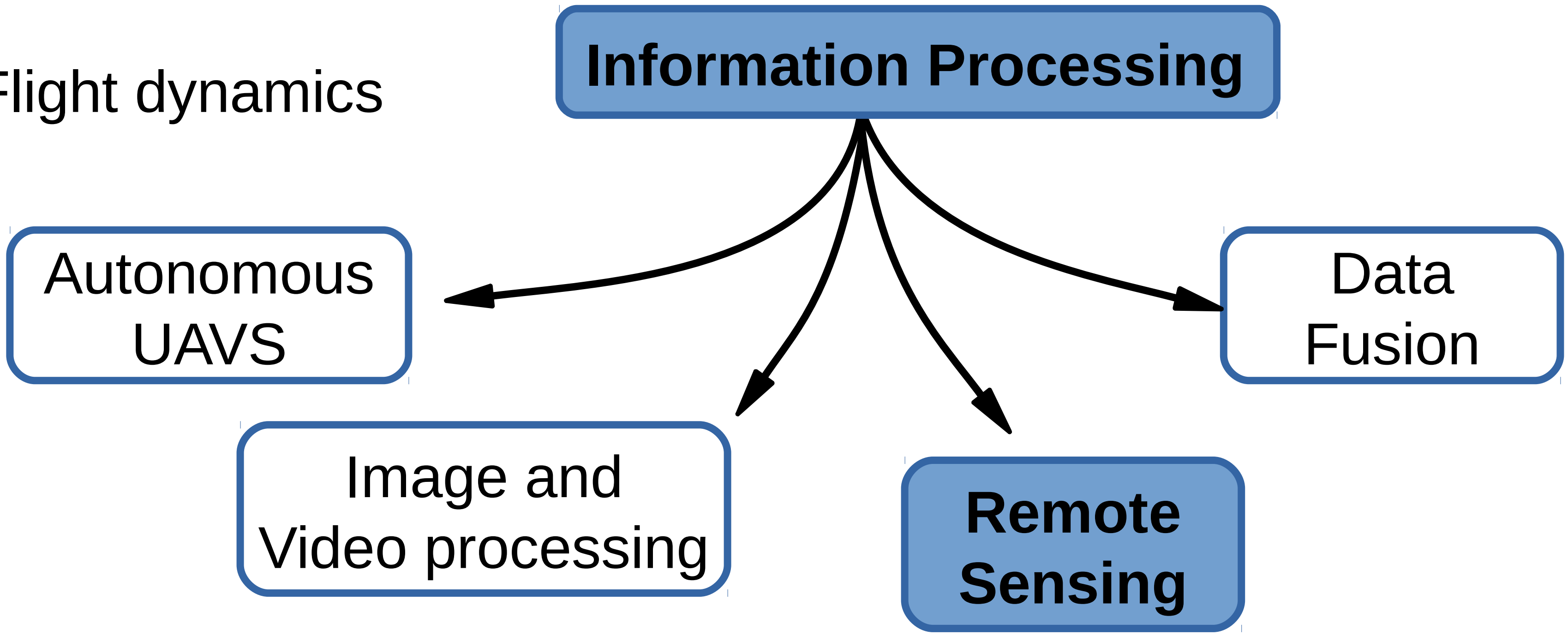
Propulsion

Optics

Electromagnetism

Aerodynamics

Flight dynamics

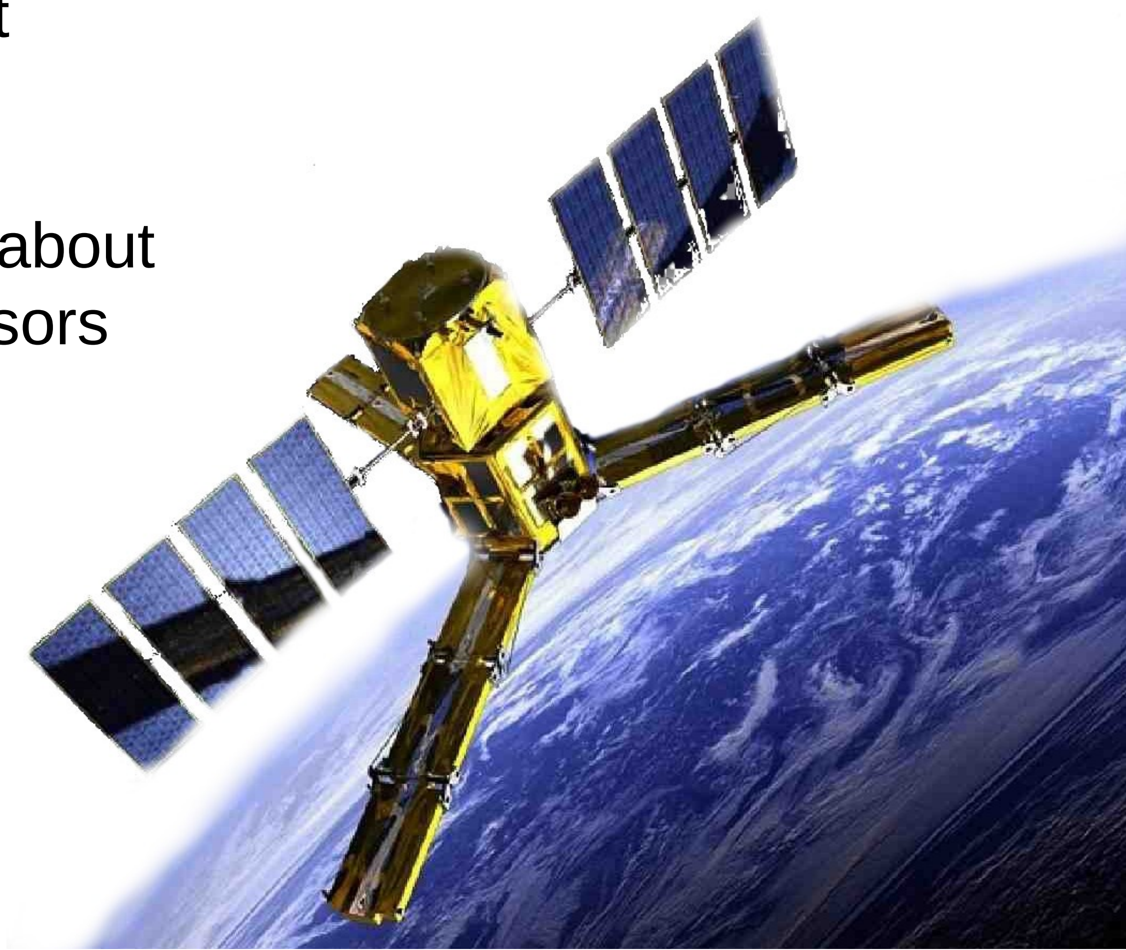


Remote Sensing

Remote Sensing
Obtaining information about objects without contact

Earth Observation
Gathering information about Earth via Remote Sensors

- **aerial**
- **spatial**
- ground



Remote Sensing

Massive data

Satellites constellations covering the earth. e.g. Sentinel (ESA)

Applications examples

- Urban area analysis

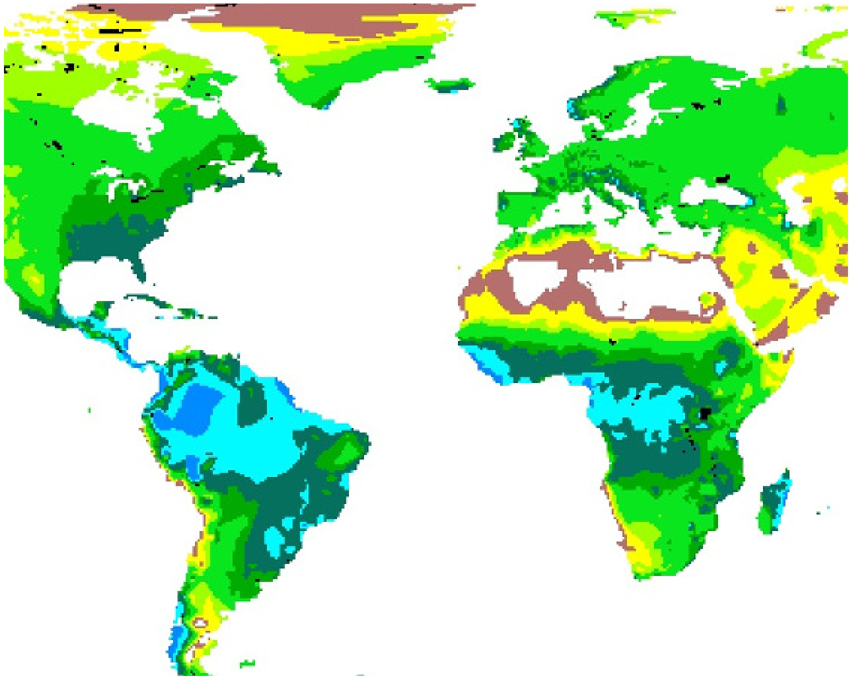
Remote Sensing

Massive data

Satellites constellations covering the earth. e.g. Sentinel (ESA)

Applications examples

- Urban area analysis
- Biomass estimation



Remote Sensing

Massive data

Satellites constellations covering the earth. e.g. Sentinel (ESA)

Applications examples

- Urban area analysis
- Biomass estimation
- Oil spread detection
- MNT estimation
- Building deformation from space

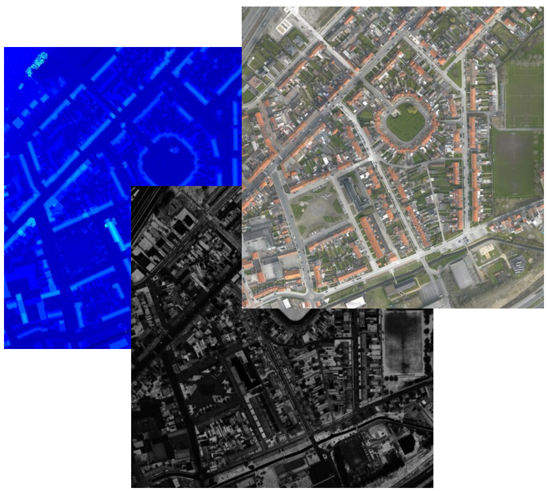
Need for robust, automatic and fast processing

Objective

INPUT DATA

Registered aerial or spatial images

Heterogeneous sources:
- RGB
- Hyperspectral
- LIDAR
- SAR ...

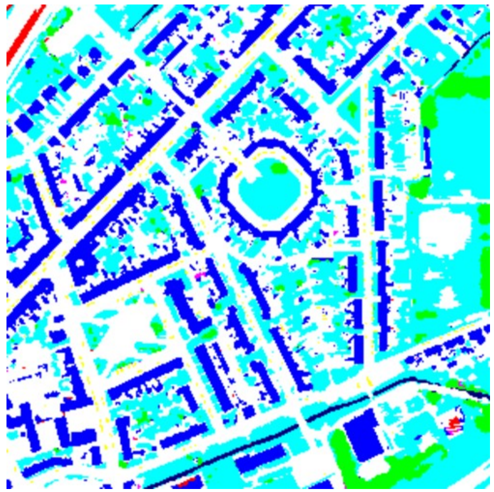


Machine Learning

SEMANTIC MAP

1 label per pixel

E.g. Tree, Building, Roads,...



Classification problem

Labels:

Car
Dog
House
Plane
Toy
Game
Ball
Cat
Road
Tree
Lego
Ski
Food
Pillow
Sun
Flower
...

Images + Labels

Classification problem

Labels:

Car
Dog
House
Plane
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Game
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Pillow
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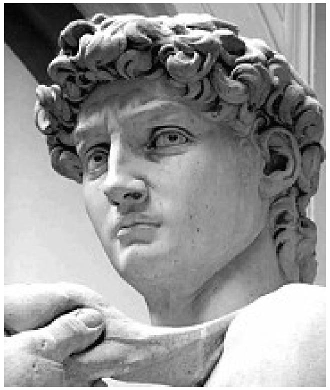
Flower
...

Images + Labels —— Annotated images

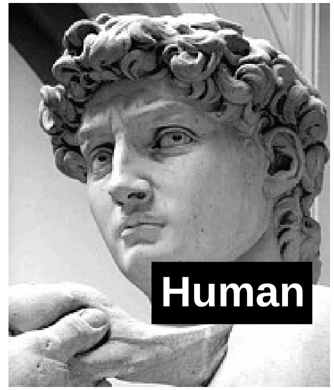
Classification framework



Image

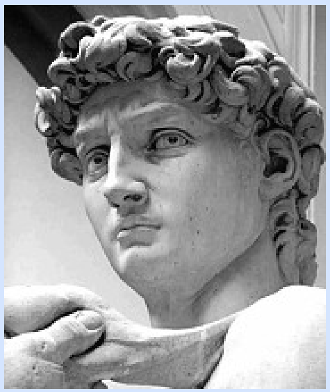
Direct classification is difficult

Classification



Annotated image

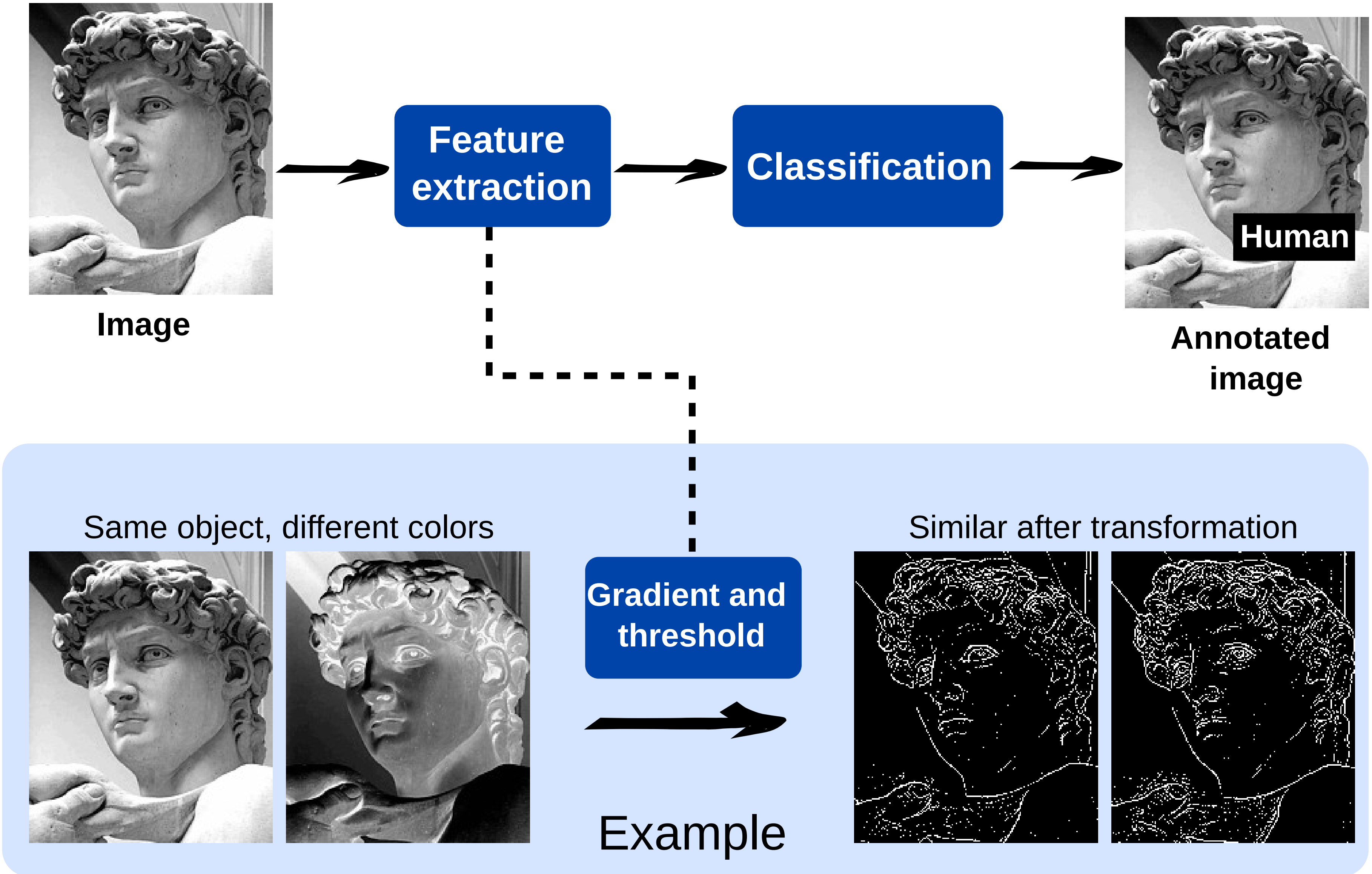
Same object, different colors



Example

Image space :
- High dimension (Image space)
- No structure of the image
- Not robust to changes

Classification framework



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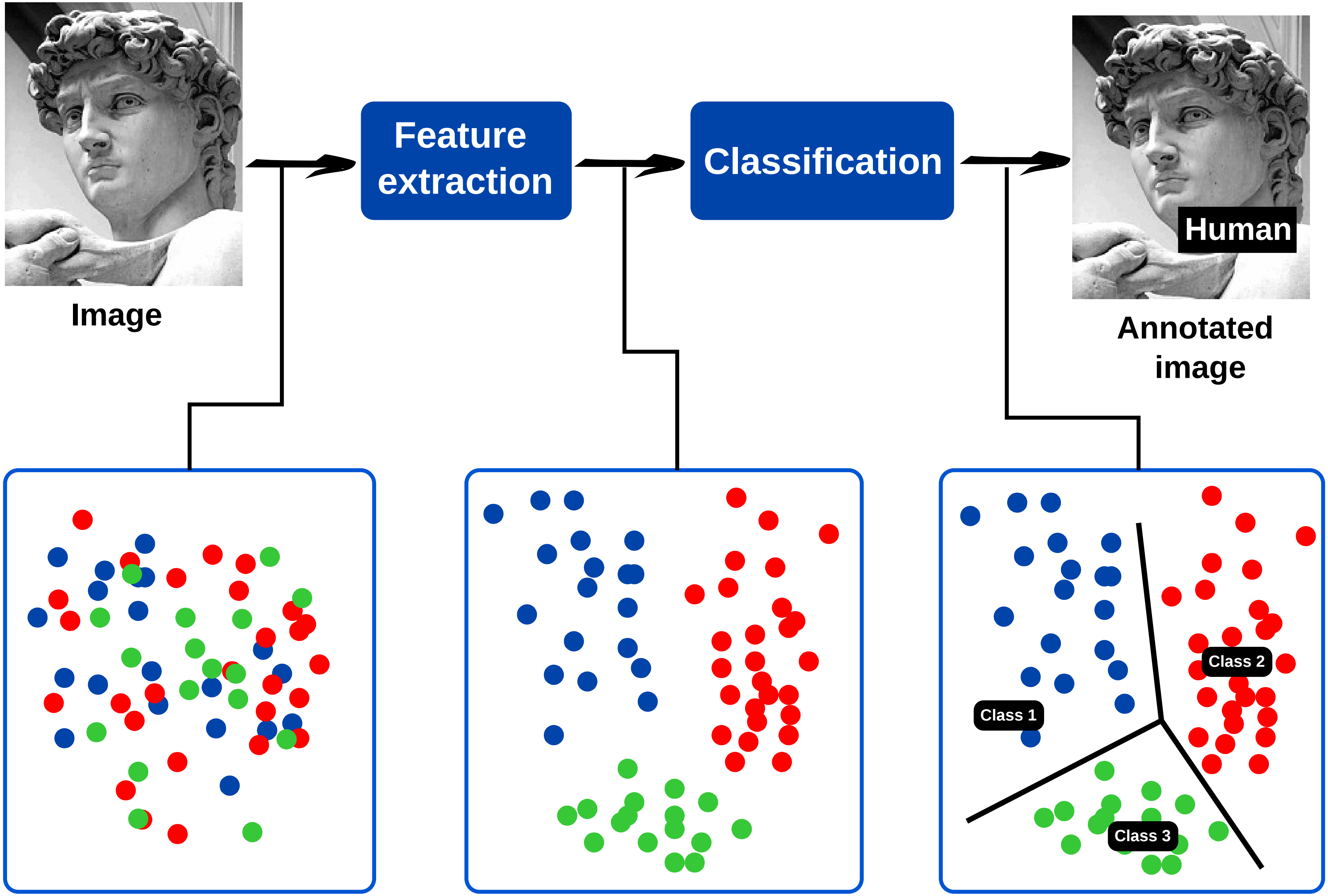
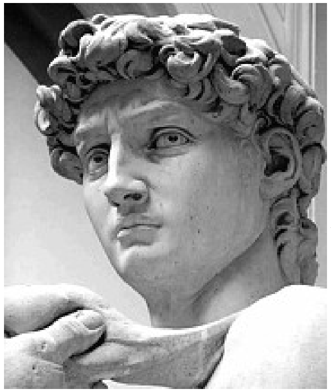
Classification framework



How to do it ?

Expert features

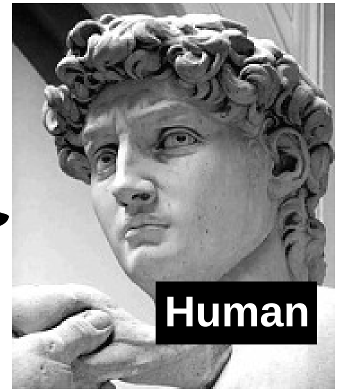


Image

Feature extraction → **Classification**

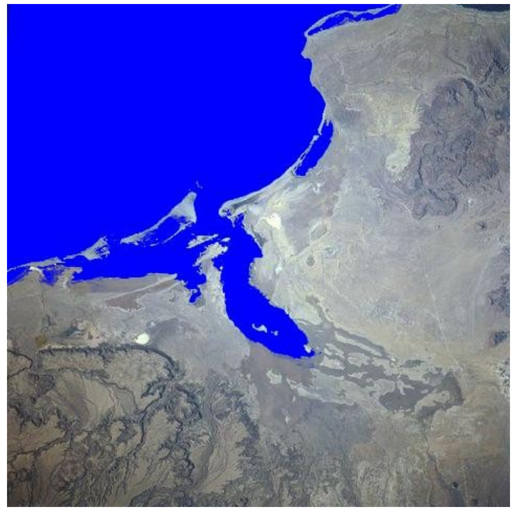
Emprical rules

Emprical thresholds or SVM

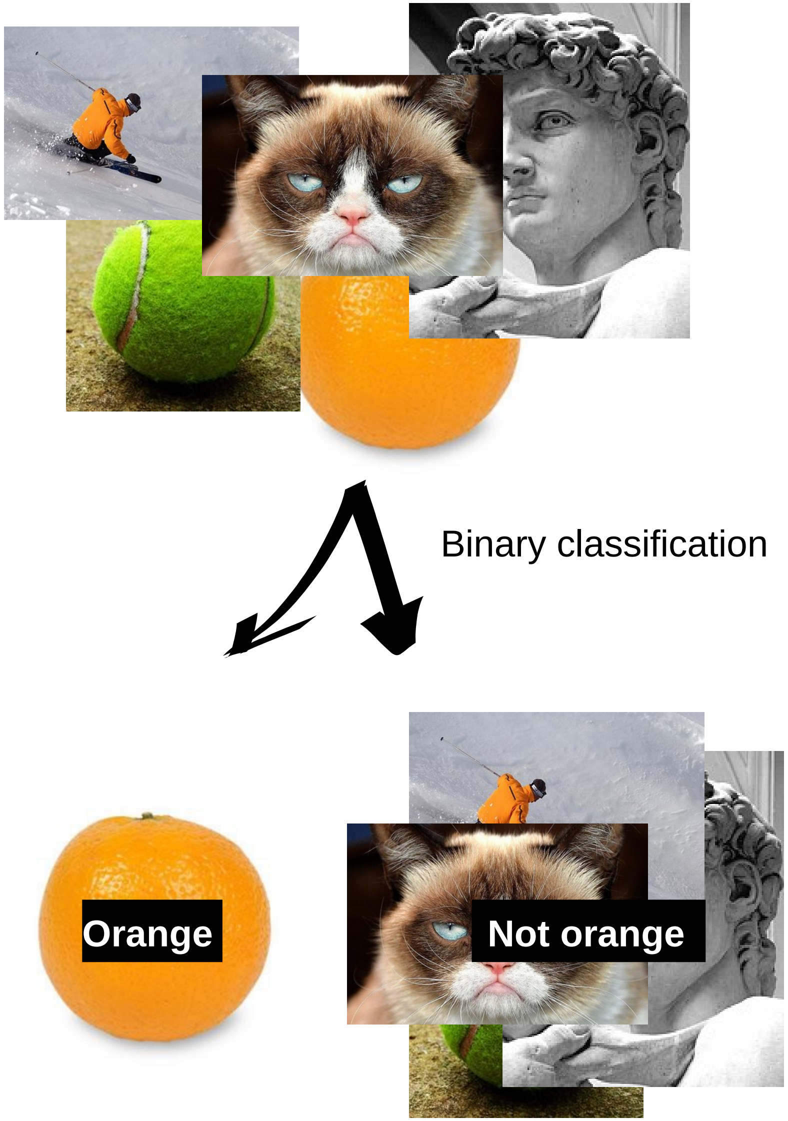


Annotated image

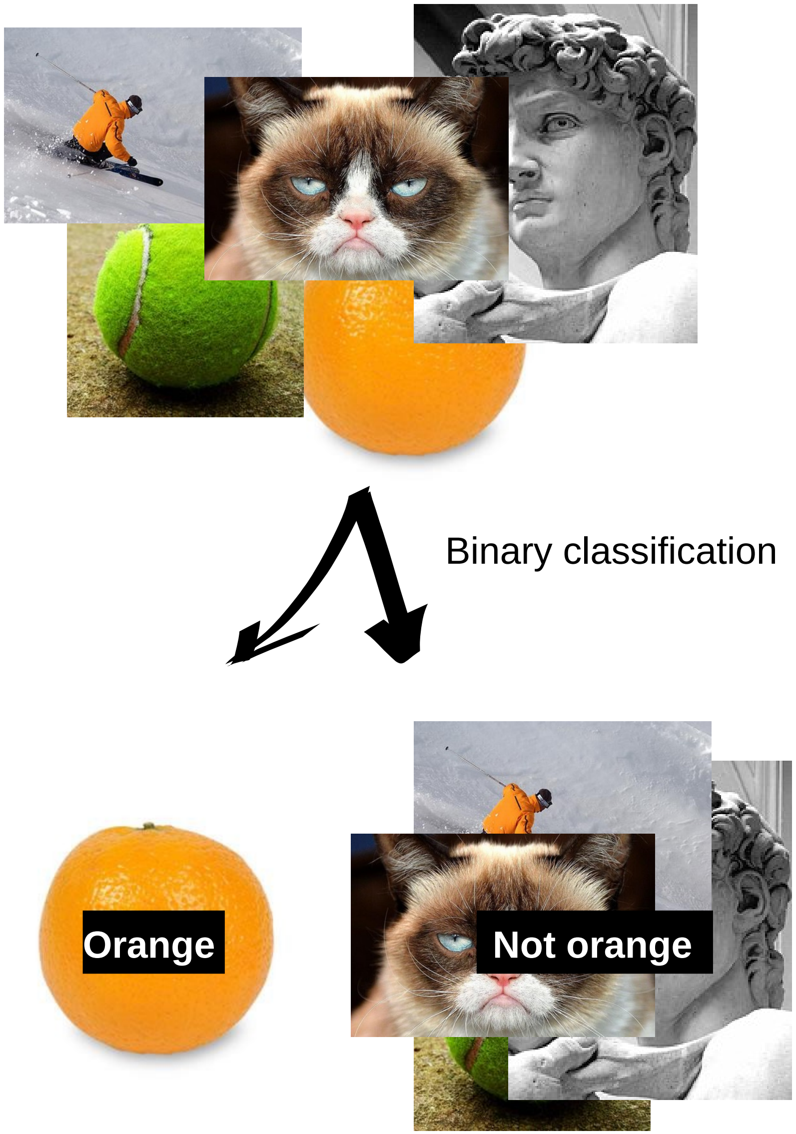
Water is blue
+
blue level > 200
green & red < 100



Designing features is difficult

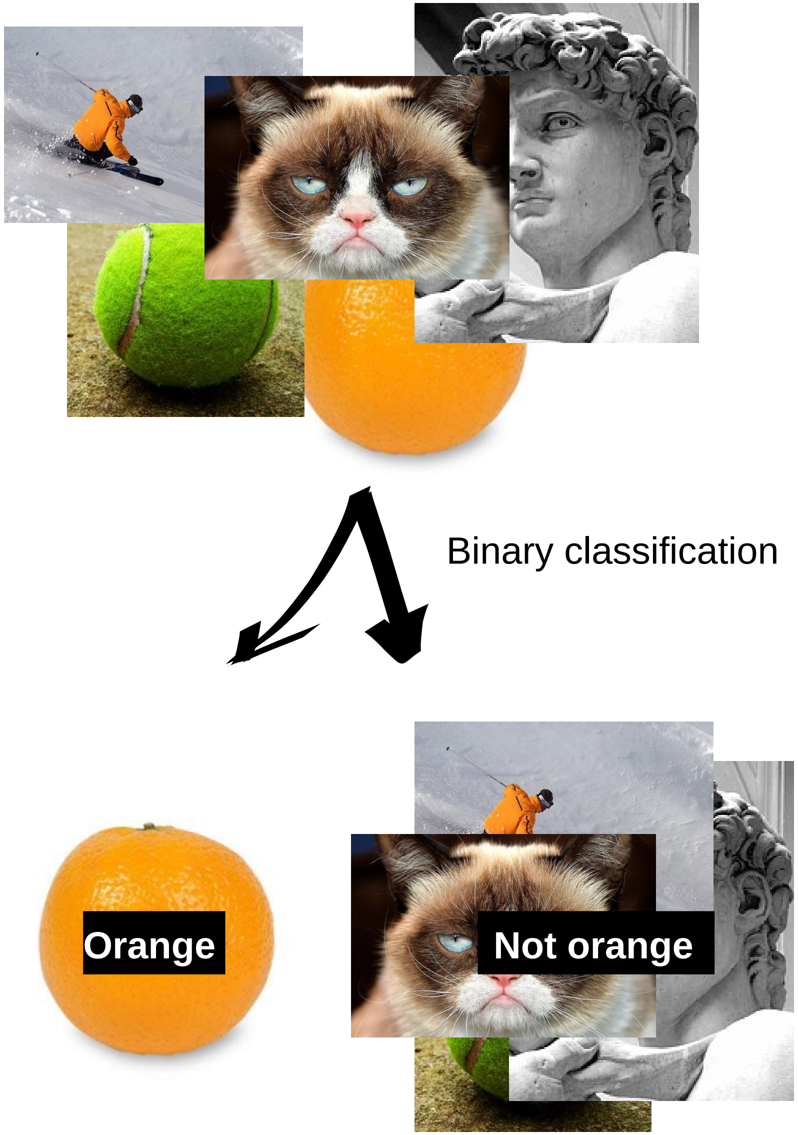


Designing features is difficult



What is a good and generic description of oranges ?

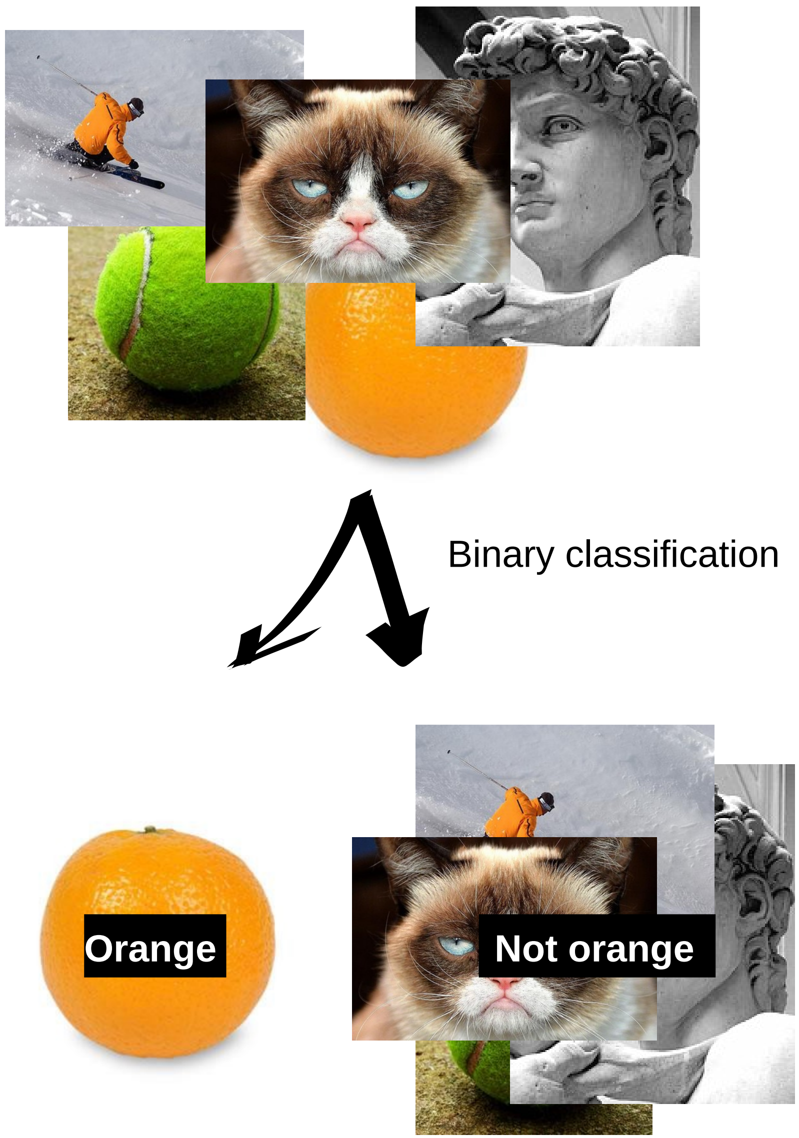
Designing features is difficult



What is a good and generic description of oranges ?

Round

Designing features is difficult



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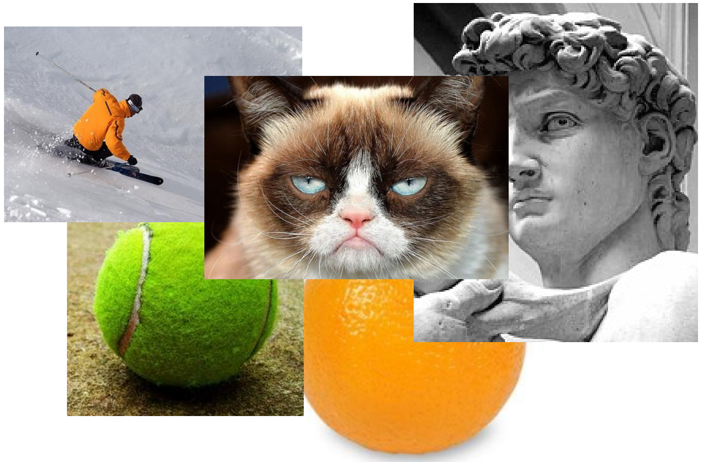
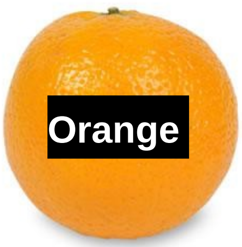
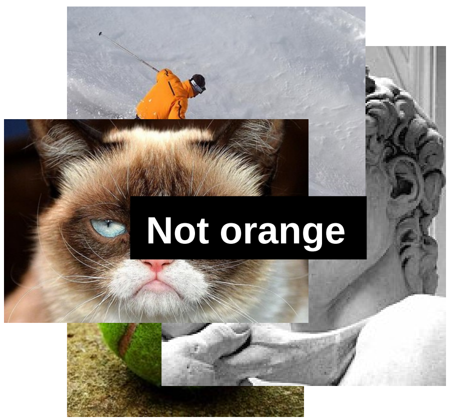


Binary classification



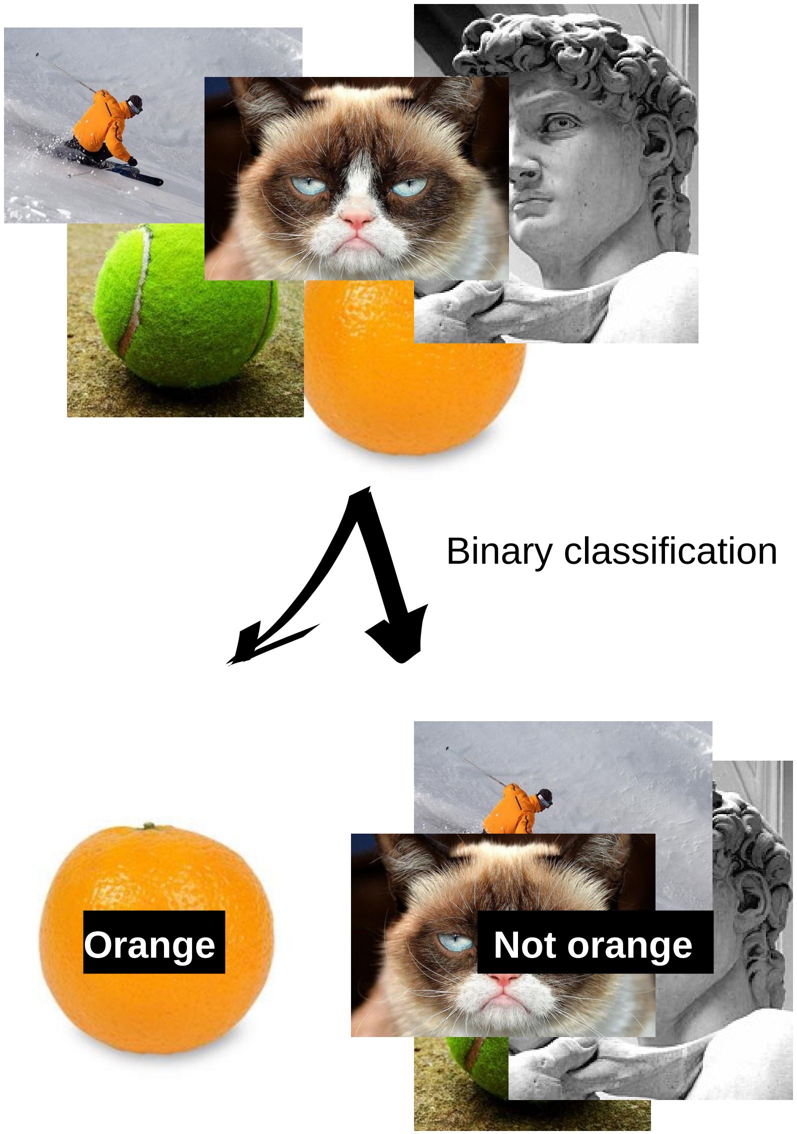


What is a good and generic description of oranges ?

Round

Color: orange

Designing features is difficult



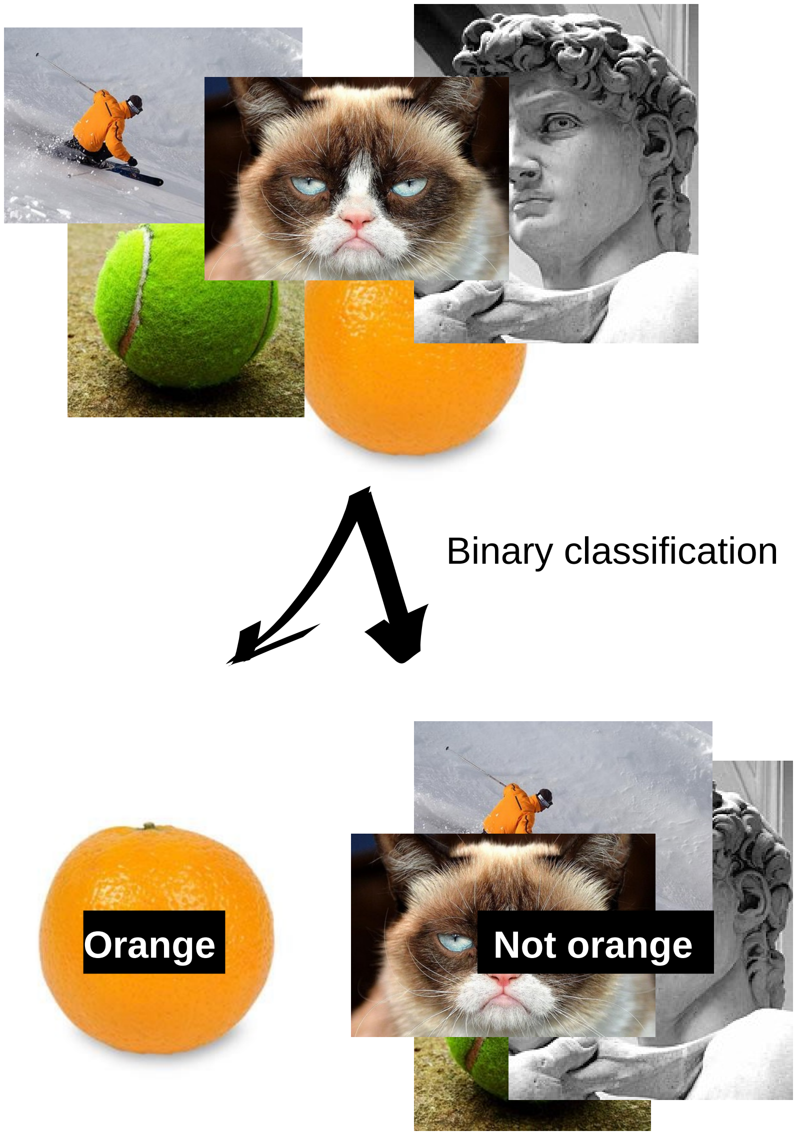
What is a good and generic description of oranges ?

Round

Color: orange

No line

Designing features is difficult

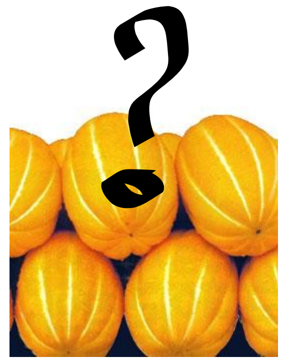


What is a good and generic description of oranges ?

Round

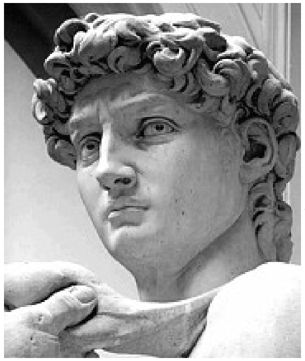
Color: orange

No line



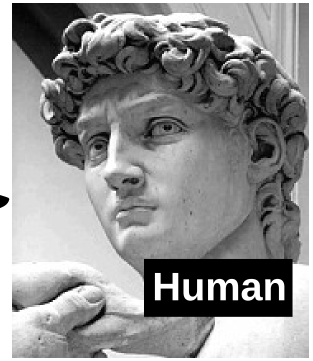
How to do it ?

Complex features



Image

Feature extraction → **Classification** →

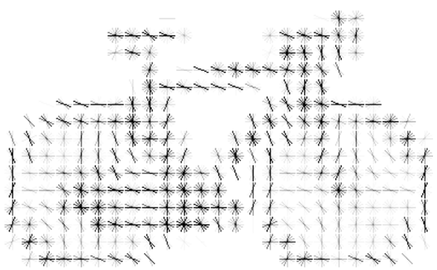


Annotated image

Complex features:
- generic features
- human design

SVM (support vector machines)

→

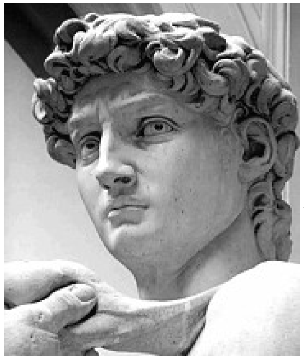


→

Histograms of Oriented Gradients (HOGs)

How to do it ?

Deep Neural Networks

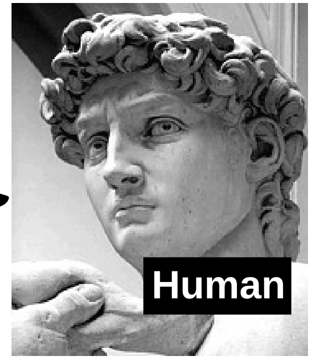


Image

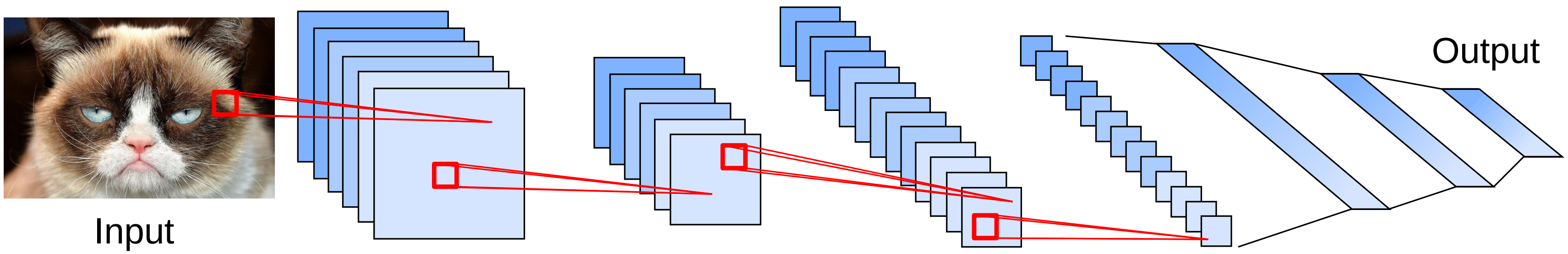
Feature extraction | **Classification**

Convolutions (First layers)

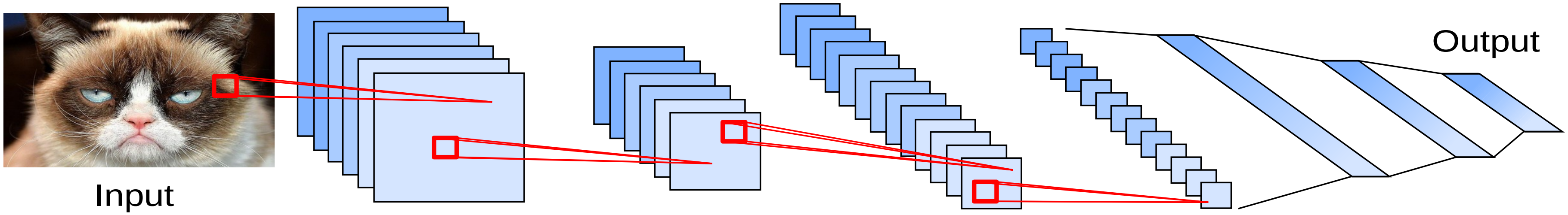
Fully connected layers



Annotated image

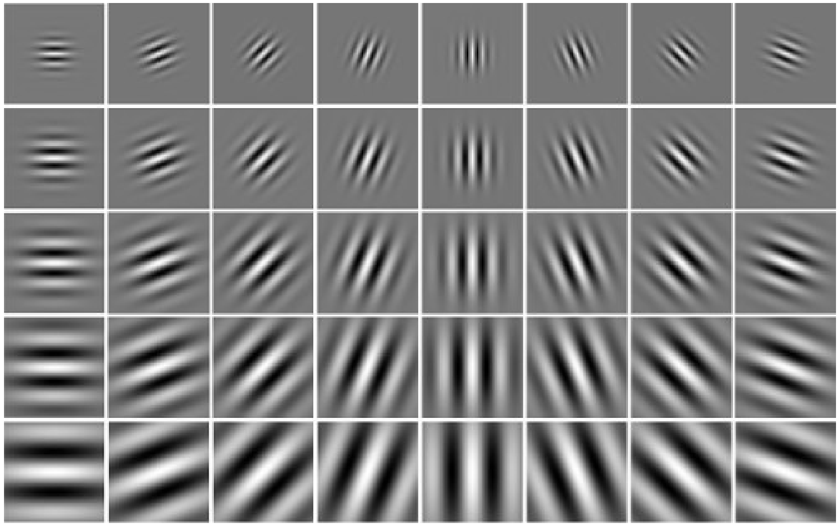


Deep neural networks



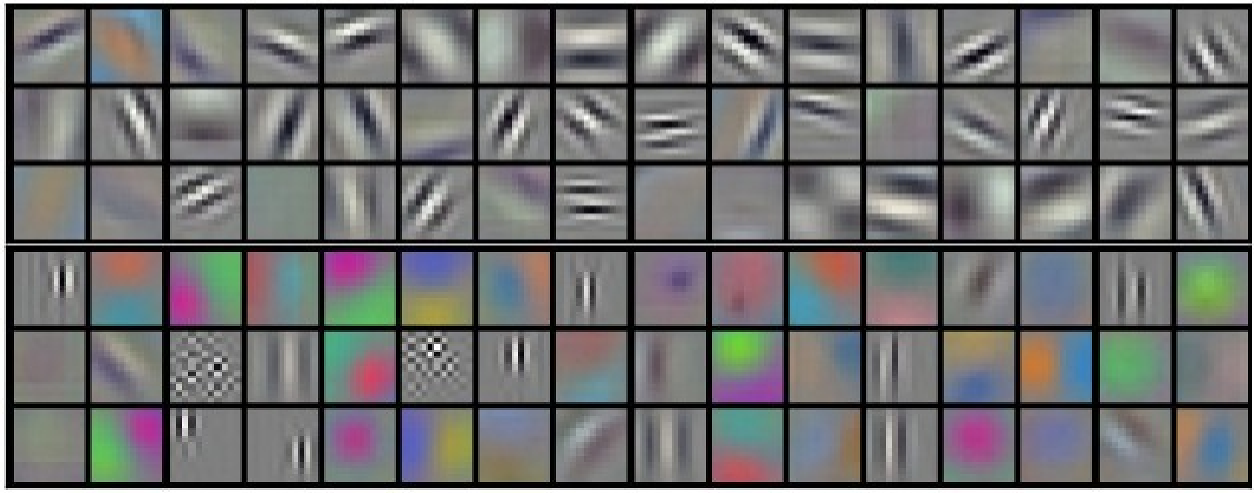
- **Two step algorithm:**
  FORWARD: predict the output given a input
  BACKWARD: compute the gradient of the loss, update the parameters of the network (back propagation)
- **A lot of parameters to optimize**
- **Efficient computing using GPUs**
- **State of the art**

First convolution layer



Gabor filters
[Daugman 1985]

AlexNet first convolution layer
[Krizhevsky 2012]



Neural networks are not new

1980's, Artificial Neural Networks

Fukushima, *Neocognitron : A Self-organizing Neural Network Model for a Mechanism of Pattern Recognition Unaffected by Shift in Position, Biological Cybernetics 36-4, 1980*

Late 1980's, Backpropagation algorithm applied to deep neural networks

LeCun et al., *Backpropagation Applied to Handwritten Zip Code Recognition, Neural Computation, 1, pp. 541–551, 1989*

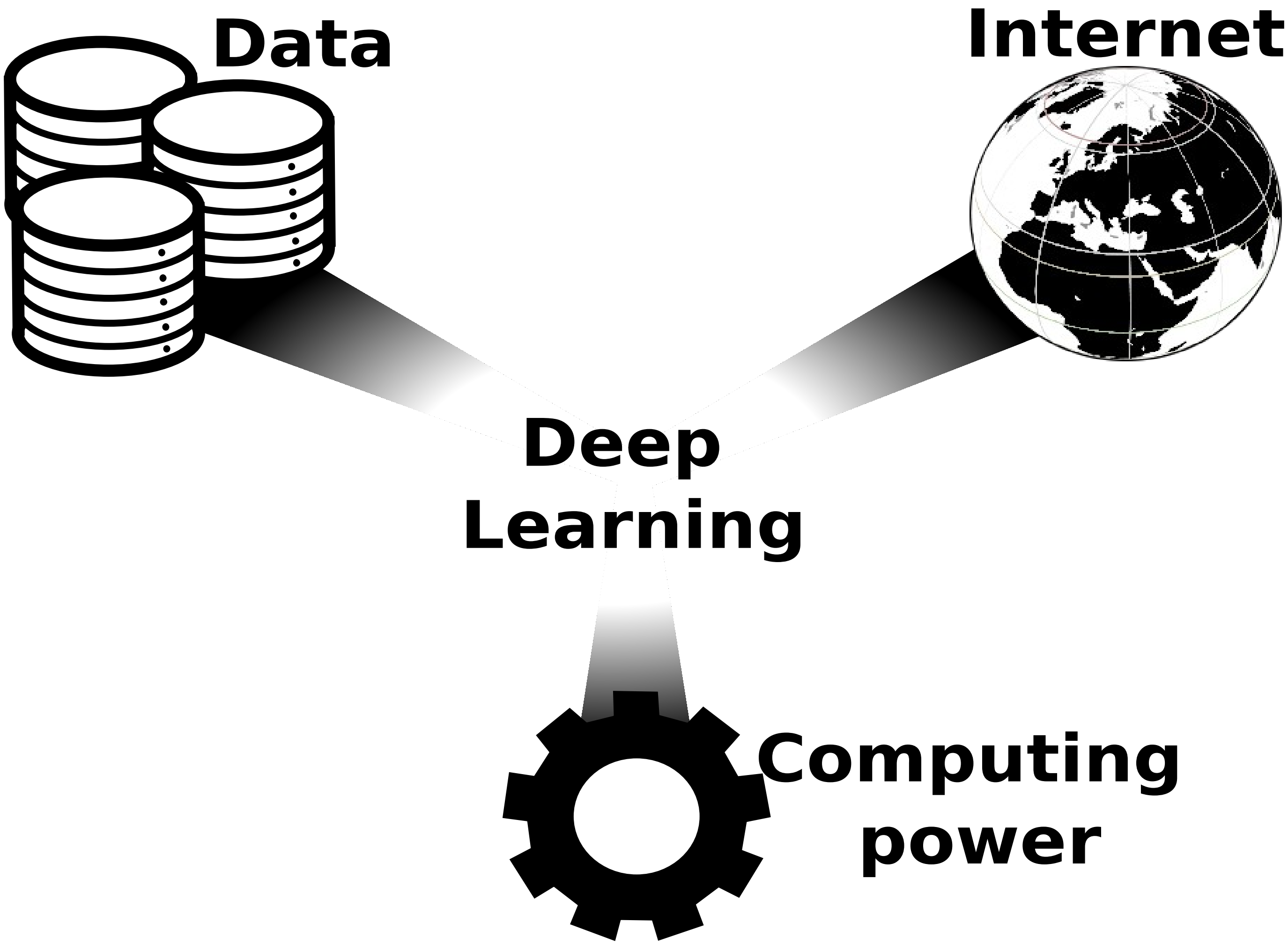
2000's, GPU implementation, renewed interest in Deep Learning

Ciresan et al., *Deep Big Simple Neural Nets for Handwritten Digit Recognition, Neural Computation, 22, pp. 3207–3220, 2010*

Since 2010:

Highly multiclass object recognition (ImageNet challenges), optical flow, segmentation. . .

What changed ?



What about Remote Sensing ?

More data available
- Sentinel
- Landsat
- …

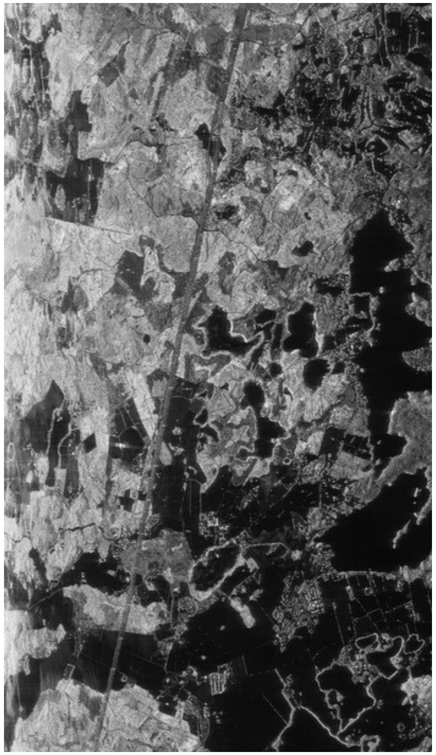
Free data
- ESA
- NSA / JPL

Platforms
- PEPS
- Google Earth Engine

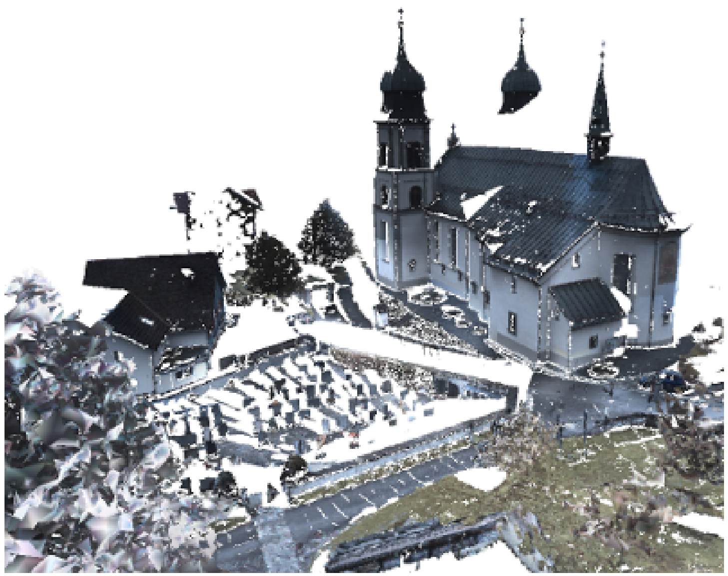
www.esa.int

Application examples

Optical
Urban
semantics

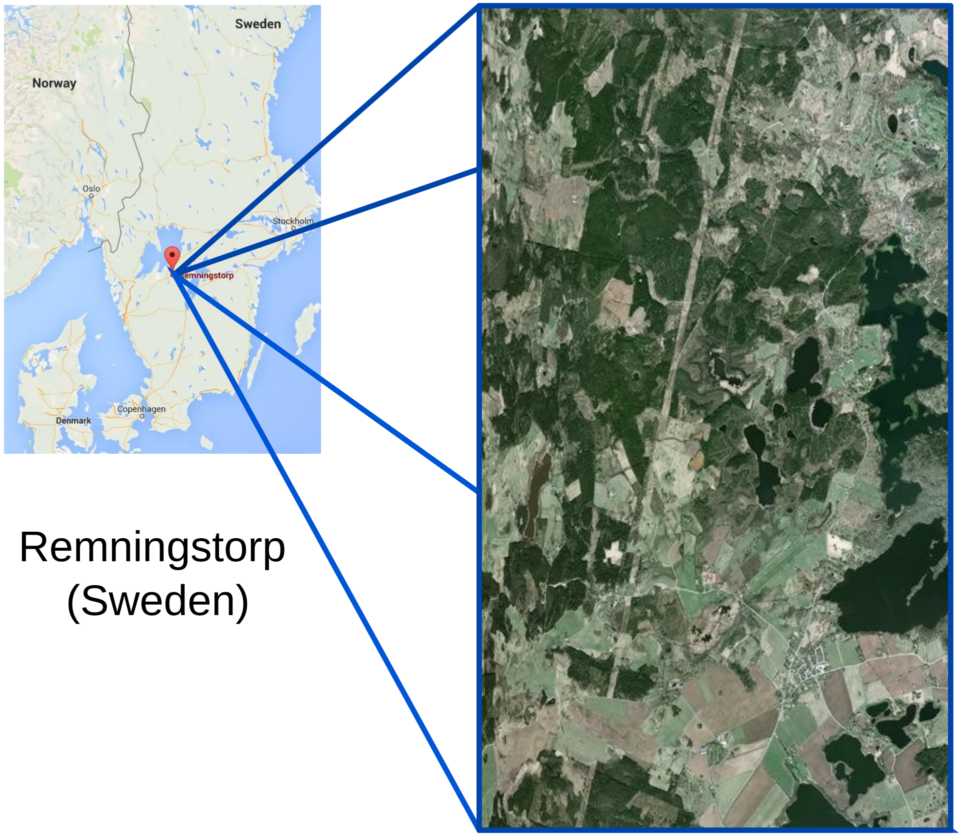


RADAR
Tree Species
recognition



3D data
Urban
semantics

Tree species recognition



Remningstorp
(Sweden)

Objective

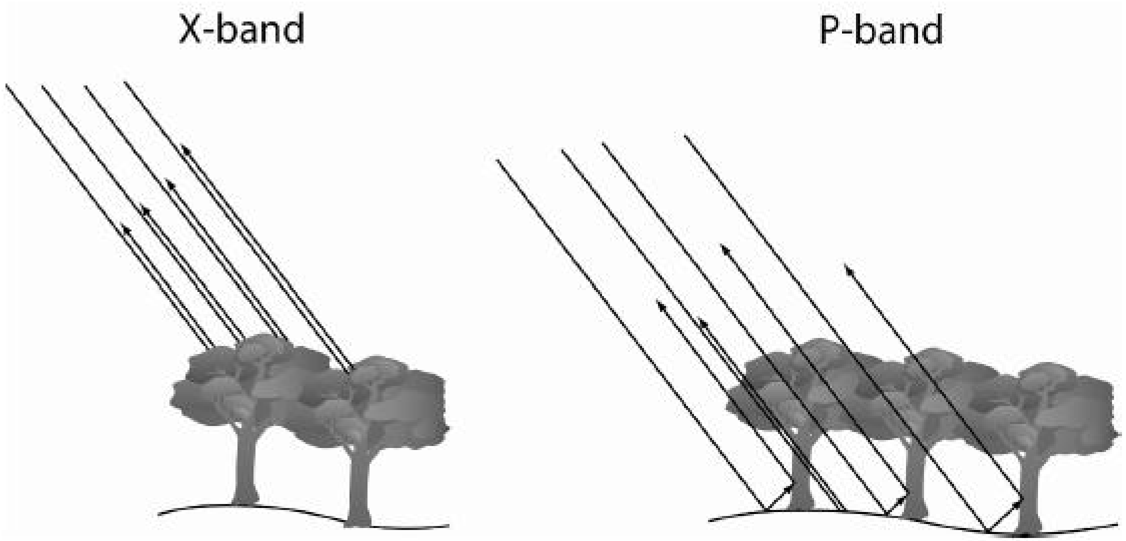
Semantic labeling of forest areas up to the species level

Challenge

Doing better than human eye.

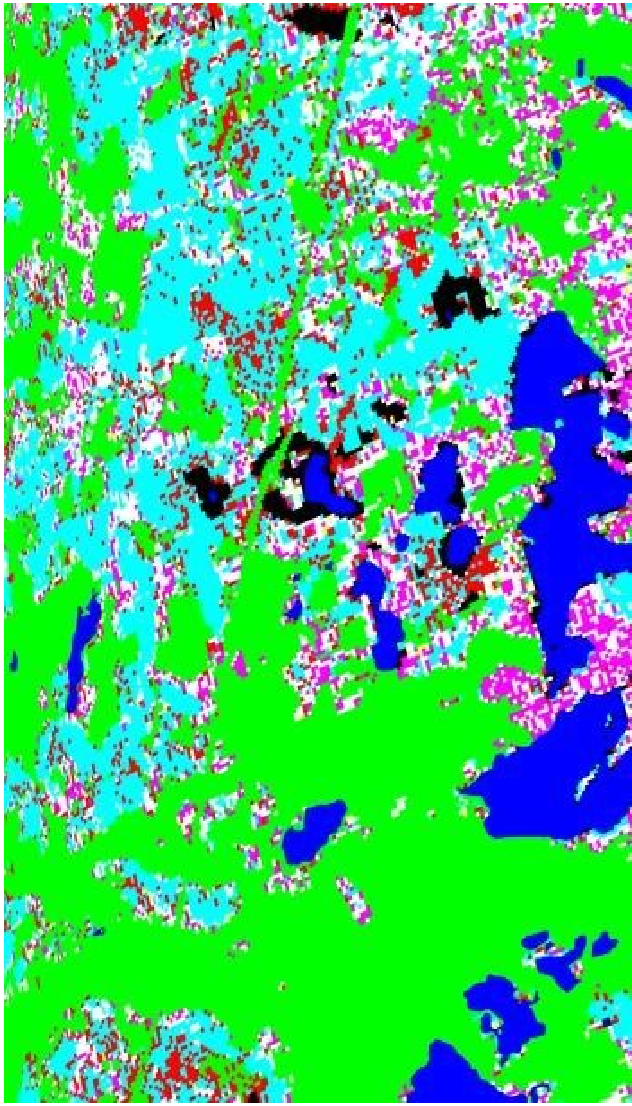
Tree species recognition with SAR data

Radar penetrates vegetation, it reflects on object with size similar to wave length.



Radar data gives information on the structure of the forest.

Tree species recognition



Generated fom open data:
Dept. of Forest Resource Management,
Swedish University of Agricultural Sciences

7 classes:

Water
No tree

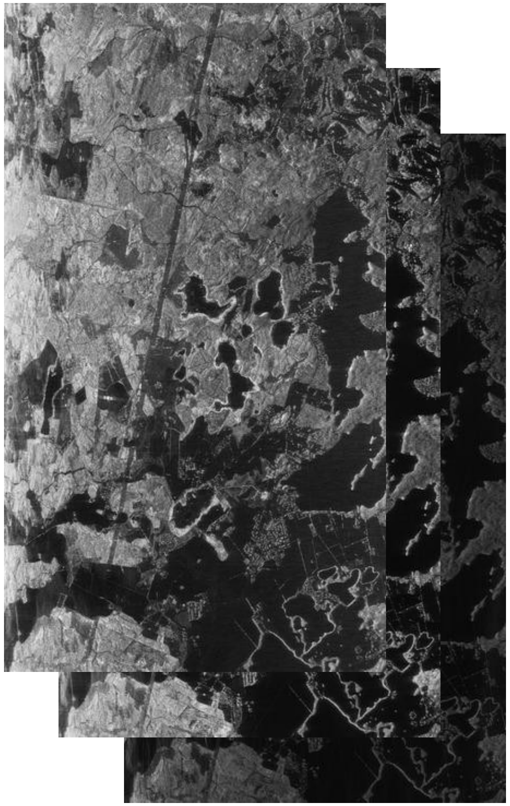
Trees:

Birch
Oak
Pine
Spruce
Misc.

Tree species recognition

SAR data

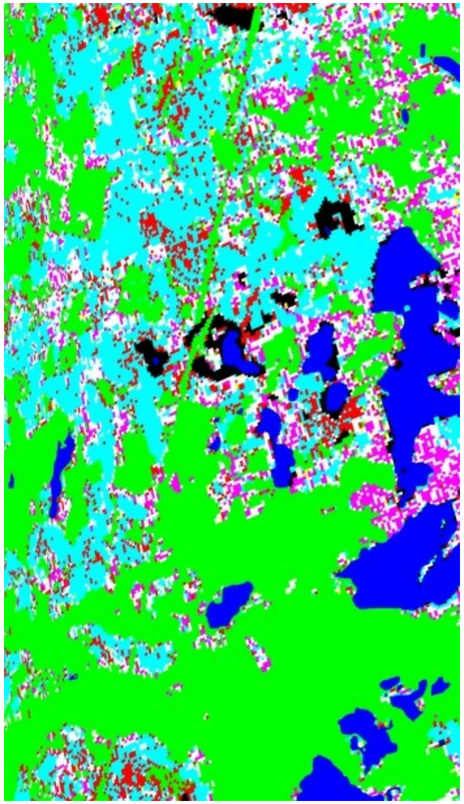
- Band P
- Polarized
- Vegetation penetration



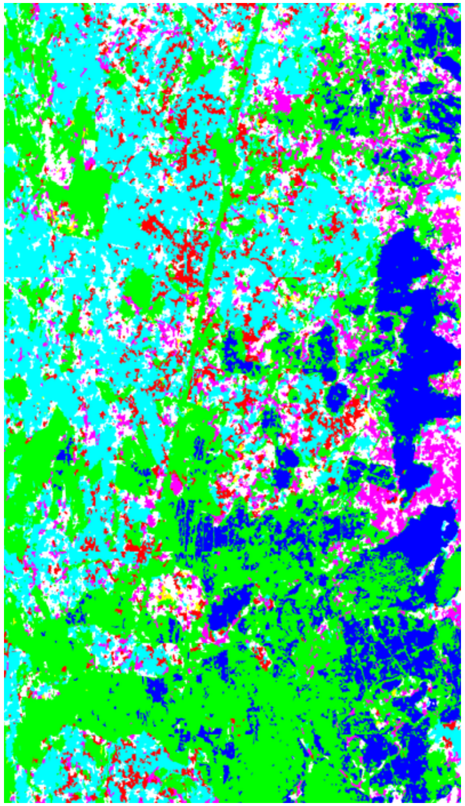
HH HV VV channels

RGB Color composition

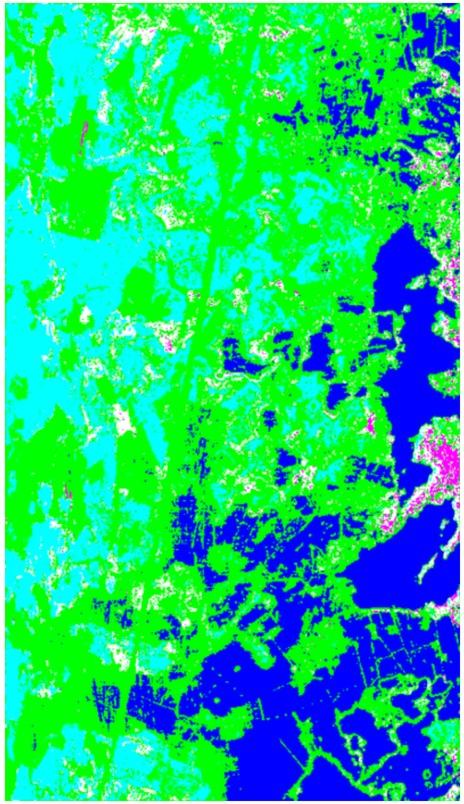
Tree species recognition



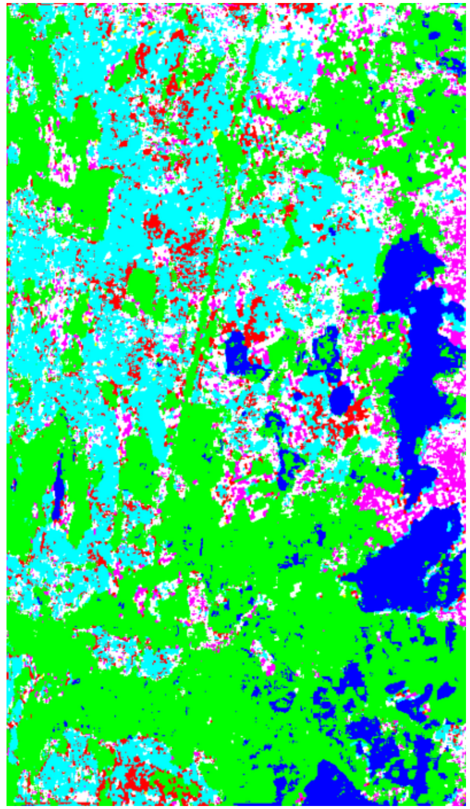
Ground Truth



Histograms and SVM

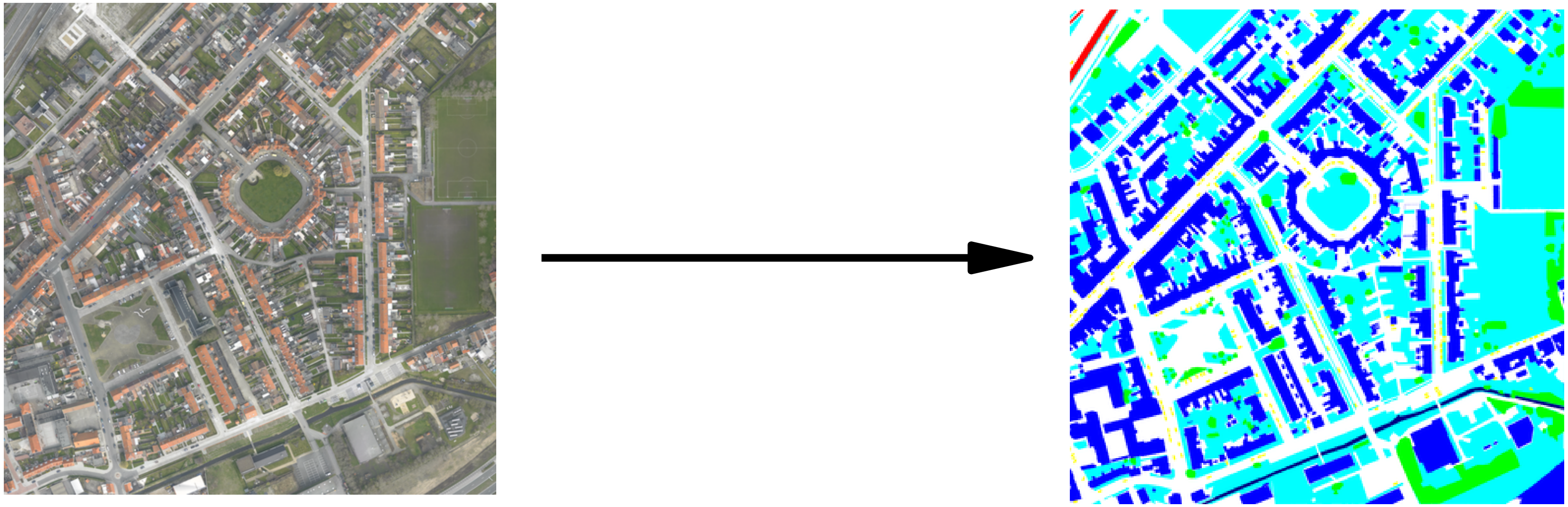


LeNet
Small neural network



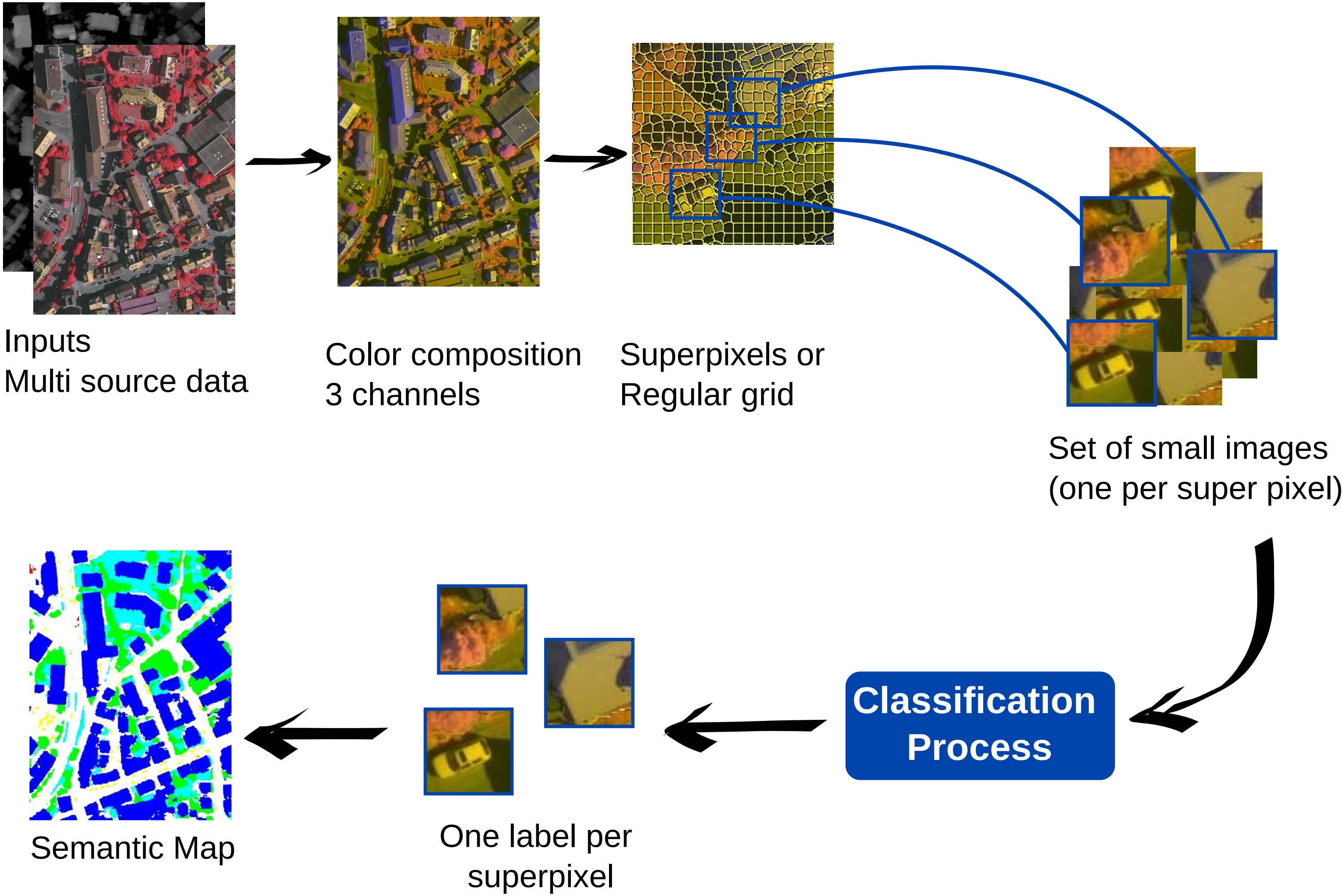
AlexNet
Large neural network

Urban semantics

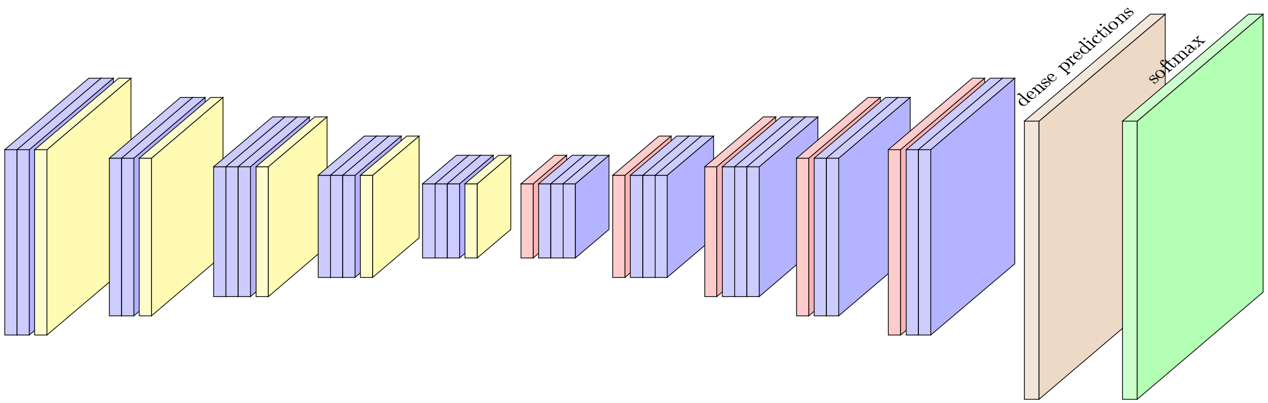


- Car park optimization
- Road mapping
- Urban extension

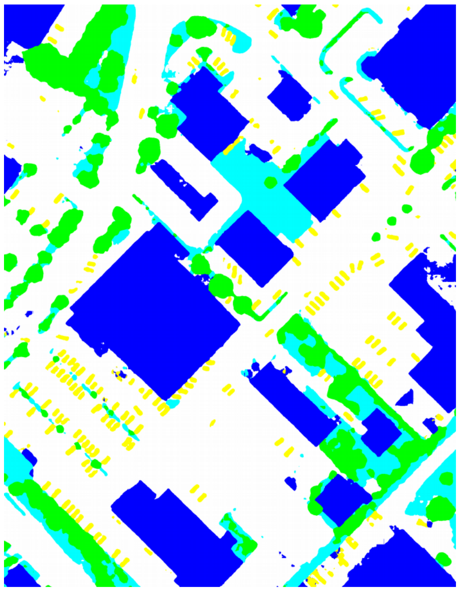
Using a classification framework



Using segmentation networks



Dense prediction



Semantic Segmentation of Earth Observation Data Using Multimodal and Multi-scale Deep Networks

Nicolas Audebert, B. Le Saux, Sébastien Lefèvre

ACCV 2016

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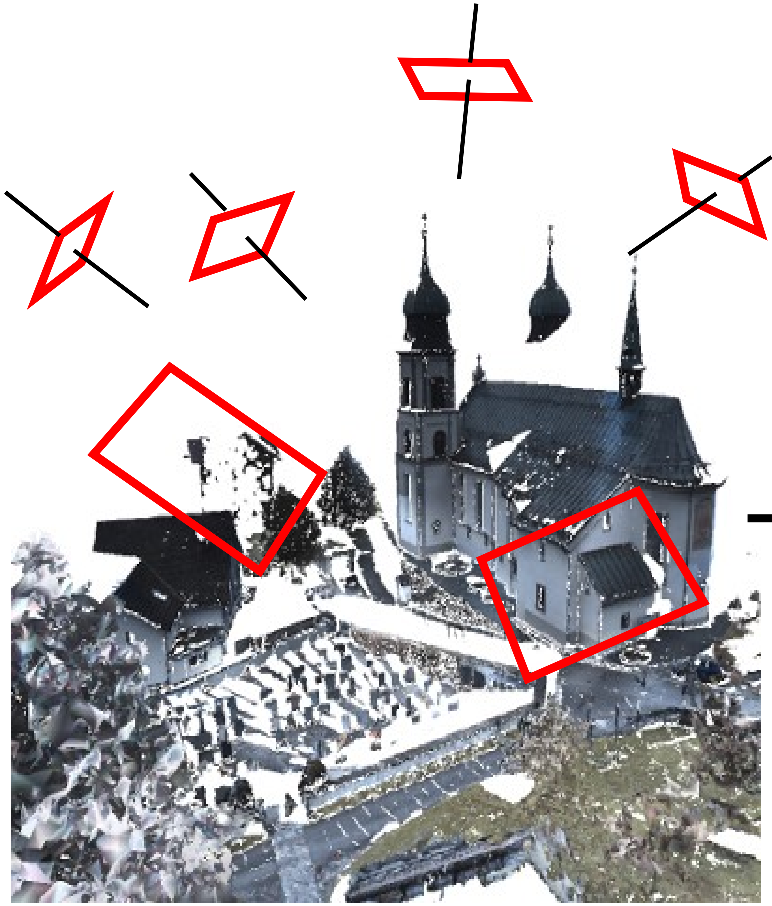
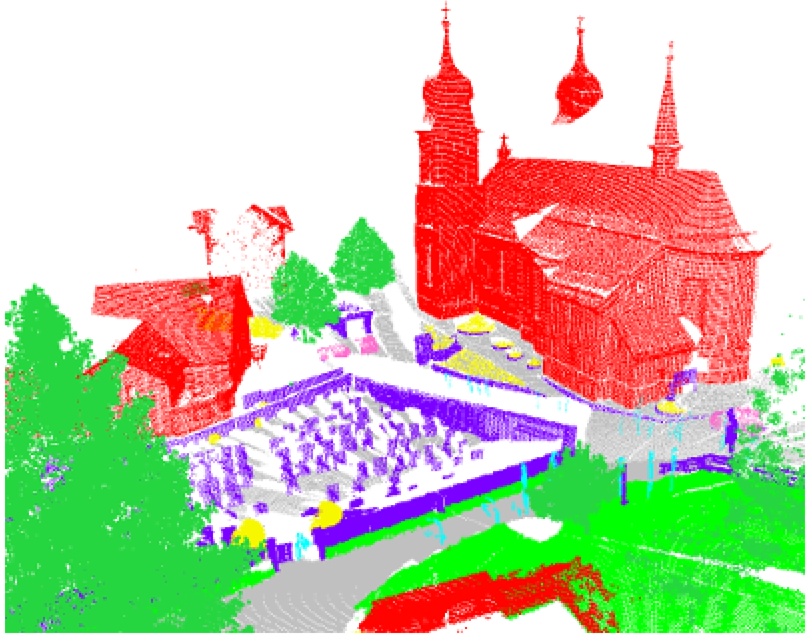
3D data semantics using segmentation networks



Pick snap shots of the
Point cloud



Project back from 2d
predictions to point cloud

First place on the Semantic 3D dataset

On going projects at ONERA

MEDUSA

Multidate Earth Observation Datamass for Urban Sprawl Aftercare

Big data for
Remote Sensing

w3.onera.fr/medusa

DeLTA

Deep learning for aerospatial

delta-onera.github.io

Intern and PhD positions

Internship opportunities

From October to January

PhD positions 2017

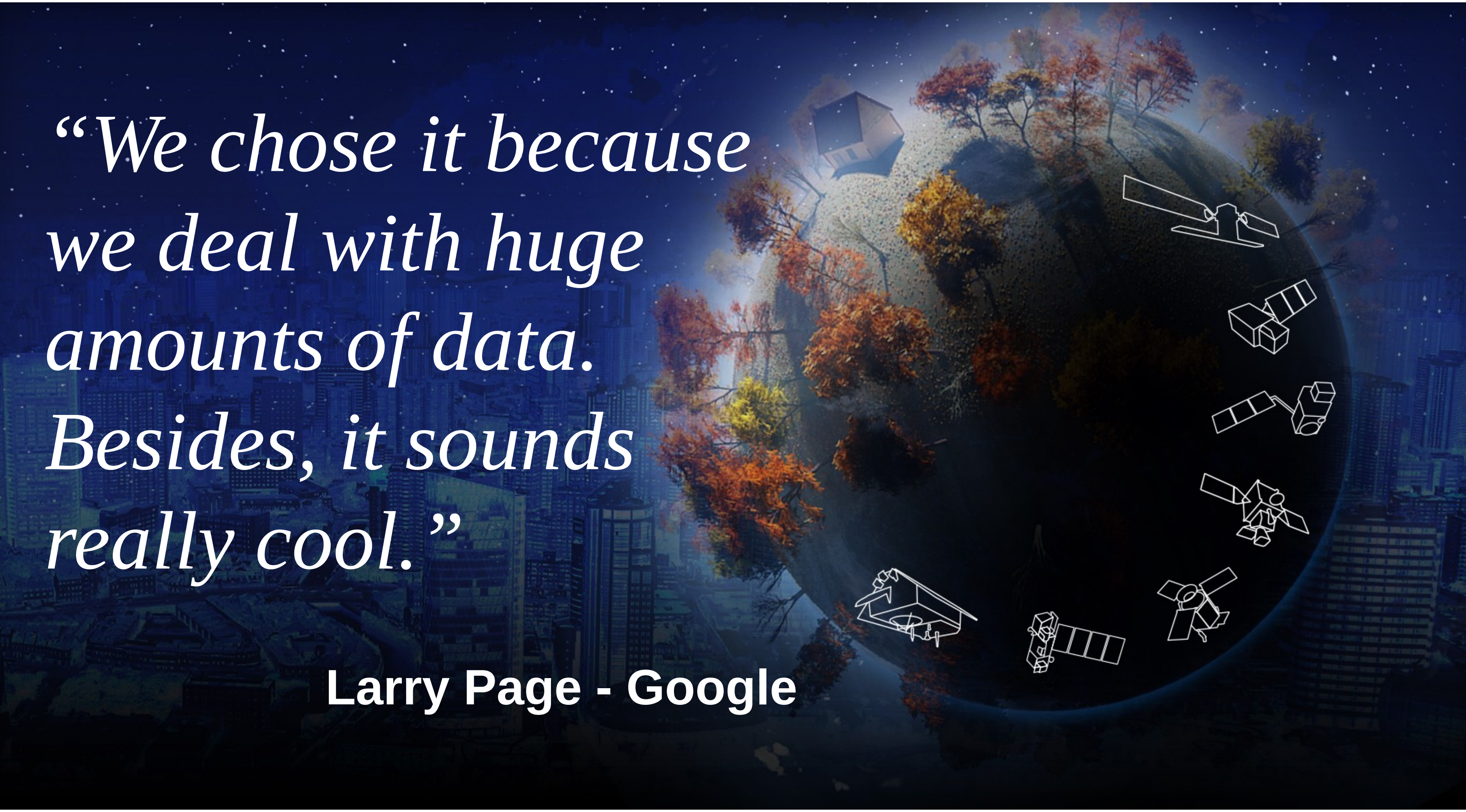
A joint geometrical and semantic approach to reconstructing digital model *(ENPC / ONERA)*

Remote sensing images registration using a deep framework *(ONERA)*

Deep learning for multi-temporal activity analysis in remote sensing *(ONERA / ENST)*

All opportunities on www.onera.fr

Conclusion



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RS in Information Processing team: Alexandre Boulch, Nicolas Audebert, Guillaume Brigot, Fabrice Janez, Elise Koeniguer, Bertrand Le Saux

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