MACHINE LEARNING

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Introduction

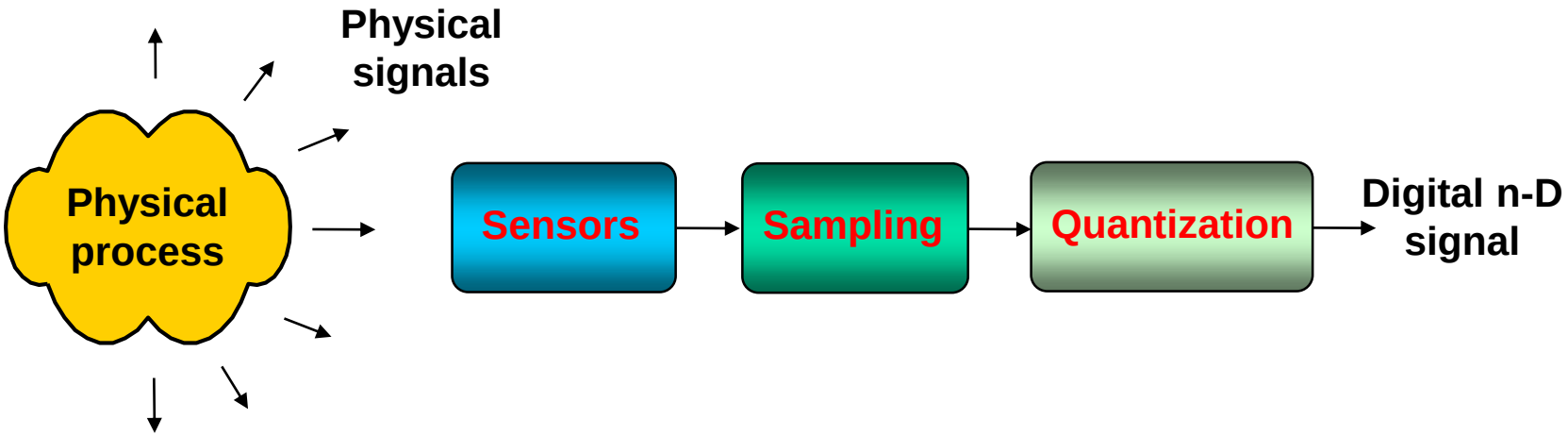
- Basic Concepts
- Machine Learning System
- Design Example
- Application Examples

Mono/Multidimensional Signals

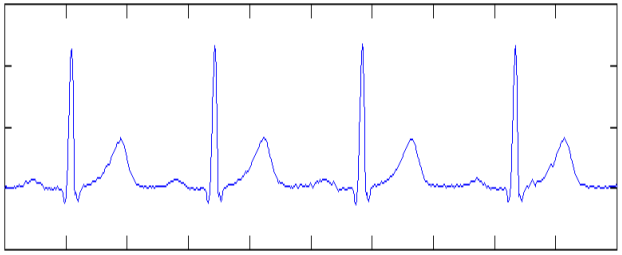
- **Signal**: a varying quantity that carries information about a physical phenomenon/process under analysis.
- **Monodimensional signal**: function $f(\xi)$ representing the information evolution with respect to a variable ξ which translates a physical reality such as time, frequency, pressure, etc…
- **Multidimensional signal**: information evolution is simultaneously related to multiple correlated or uncorrelated physical realities ⇨ $g(\xi,\gamma,\delta,....)$

Nota: Physical realities may be continuous as well as discrete variables.

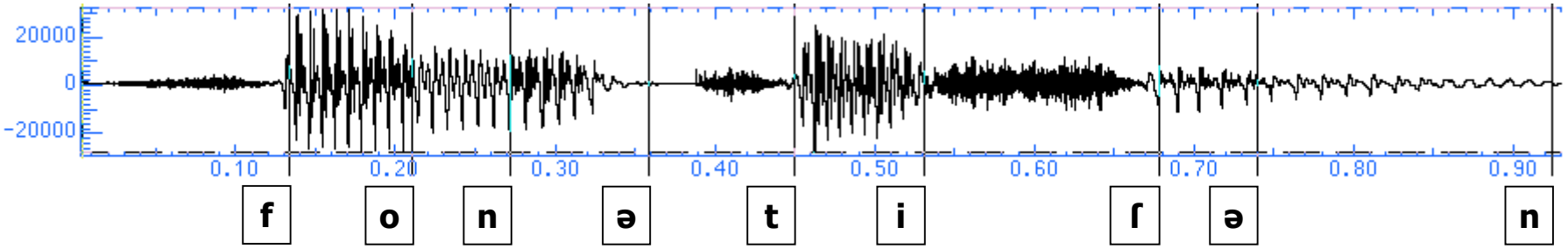
Signal Acquisition



Examples of 1-D Signals



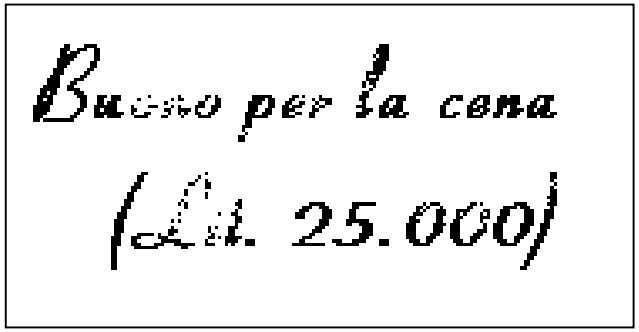
ECG signal



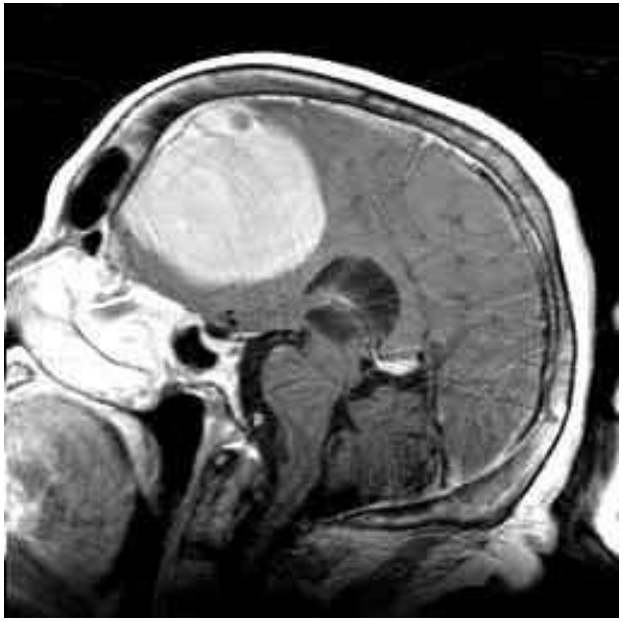
Phonetician

Speech Signal (oscillogram)

Examples of 2-D Signals

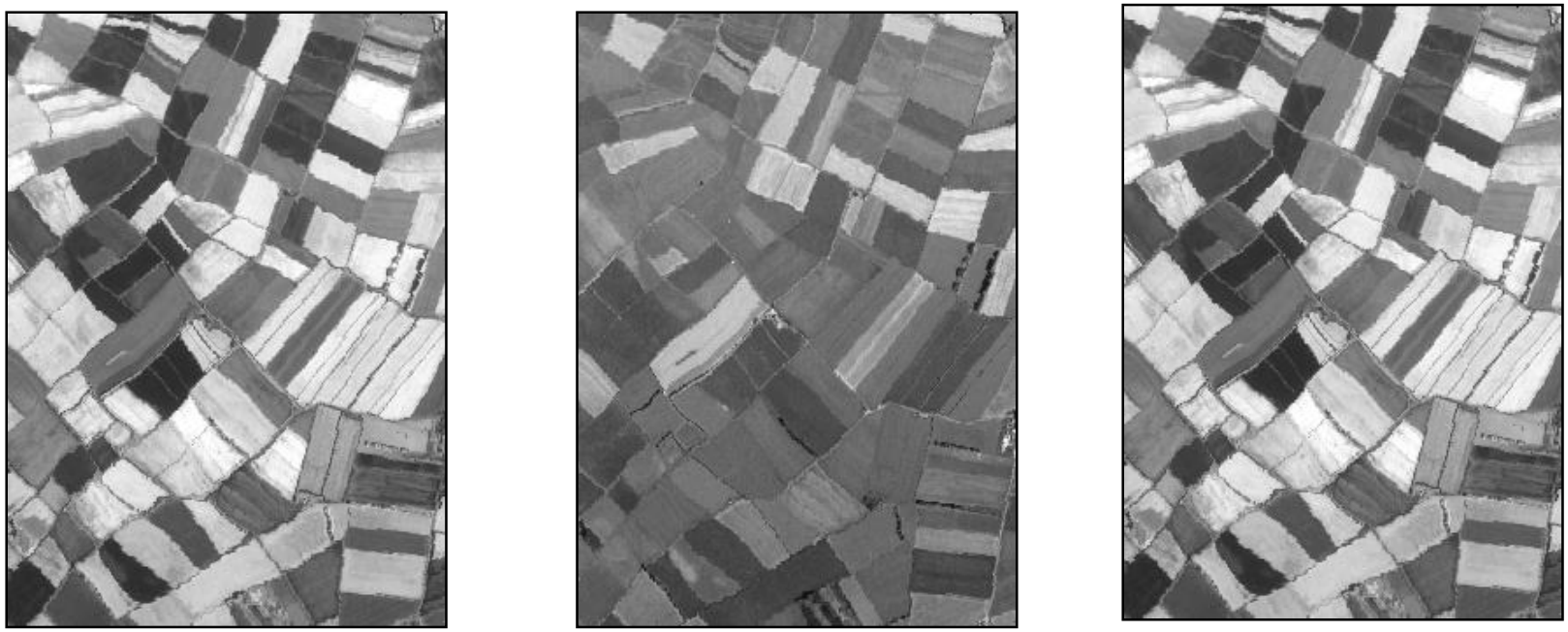


Black & White Image



Biomedical Image (10 bit)

Examples of n-D Signals



Multispectral Remote Sensing Image (8 bit, 3 bands)

Learning

- *"**Machine learning** is the study of computer algorithms that improve automatically through experience. It is seen as a subset of artificial intelligence. Machine learning algorithms build a mathematical model based on sample data, known as "training data", in order to make predictions or decisions without being explicitly programmed to do so."* (from Wikipedia).

- **Supervised learning**: the learner is fed with a set of input/output pairs (training set).

- **Unsupervised learning**: no output information is provided, but just input data which are modeled by the learner (e.g., data clustering).

Learning

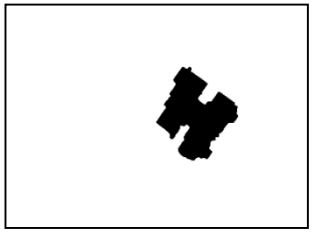
- **Semi-supervised learning**: besides a limited amount of input/output pairs, the plenty unlabeled data are exploited during the learning process.

- **Active learning**: the learner interactively queries a supervisor (oracle) to label new samples with the desired outputs.

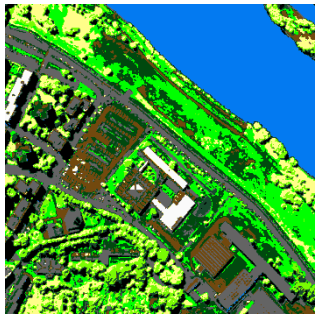
- **Reinforcement learning**: learning process of an arbitrary being (agent) in the world surrounding it (environment). The agent seeks to maximize the rewards it receives from the environment, and performs different actions in order to learn how the environment responds and gain more rewards.

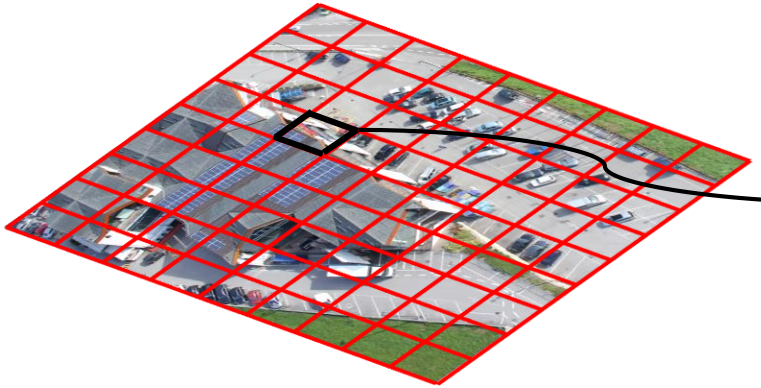
Supervised Tasks

Binary Classification



Multiclass Classification



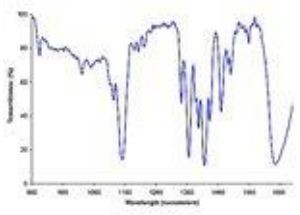


Multilabel Classification

0	Asphalt
1	Solar panel
…	…
0	Tree
1	Car

Supervised Tasks

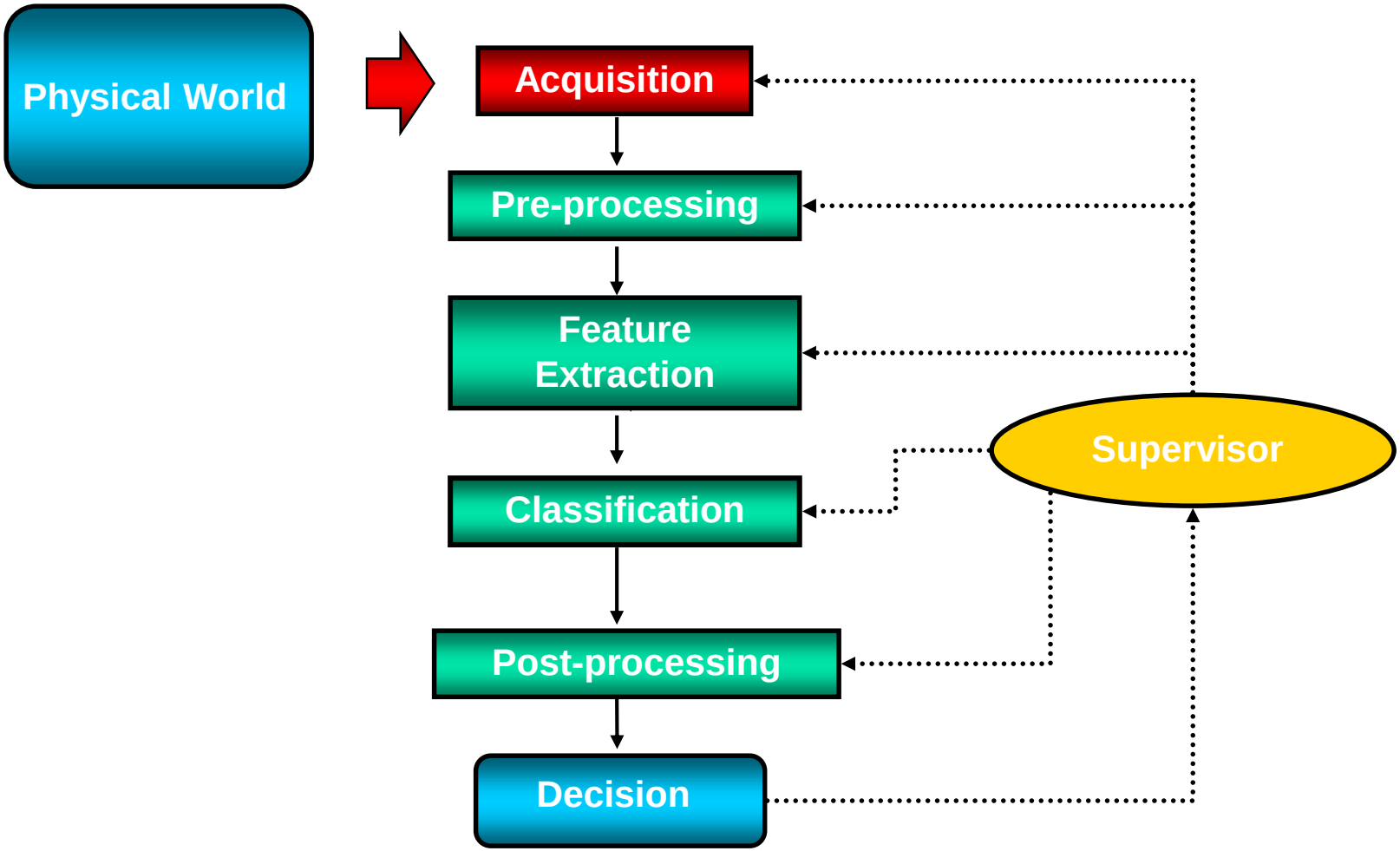
Captioning → *Eight cars on the right in a parking lot.*



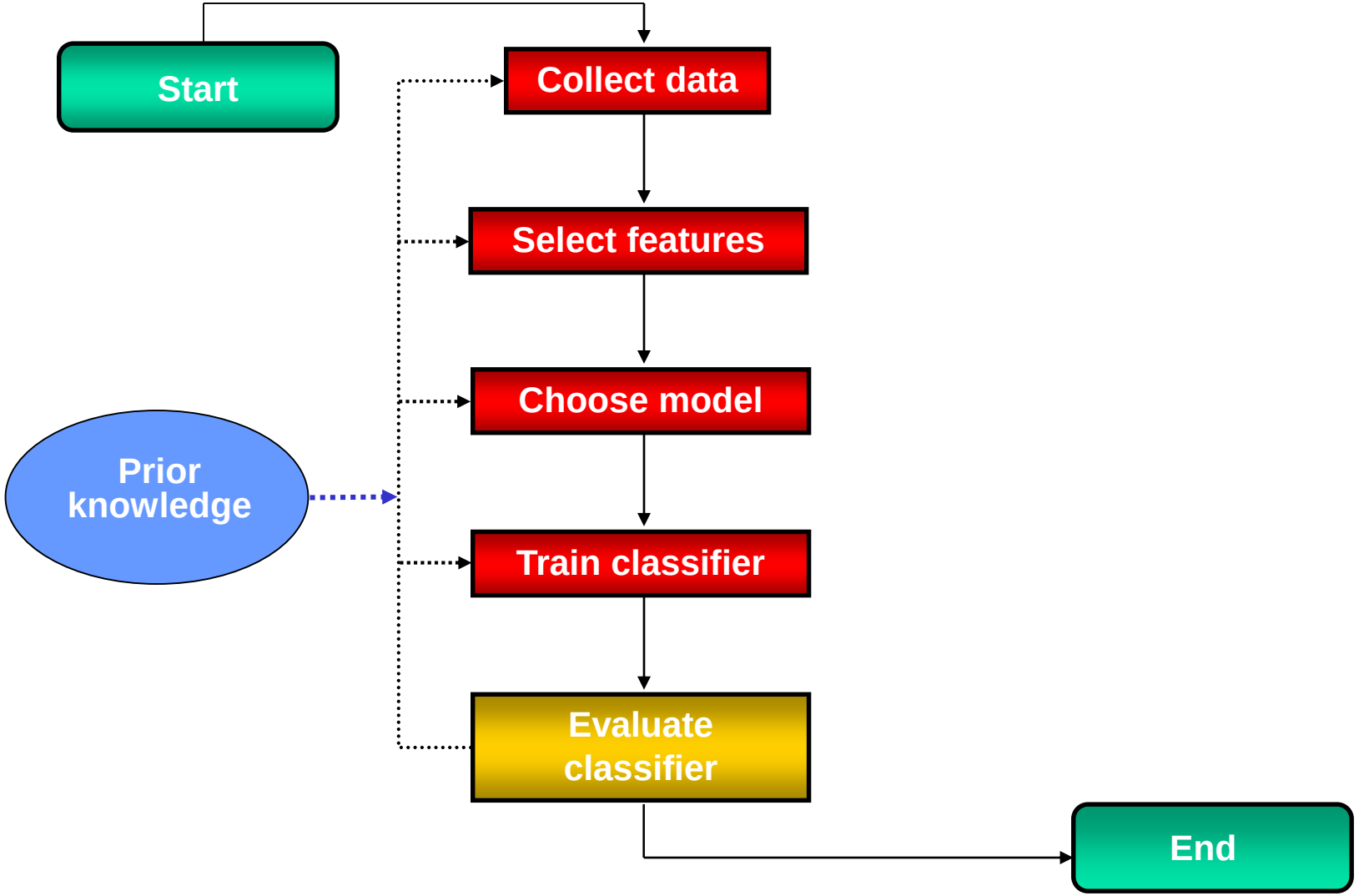
Regression → **Saccharose: 23.65 [g/l]**

Ranking → **Priority 1**

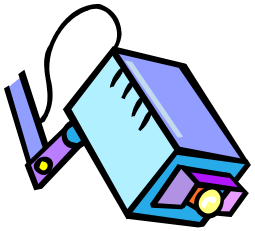
ML System: Block Scheme



ML System: Design Phases



Example: Automatic Fish-Packing Plant



Pre-processing
&
Feature Extraction

Classification

Sea bass

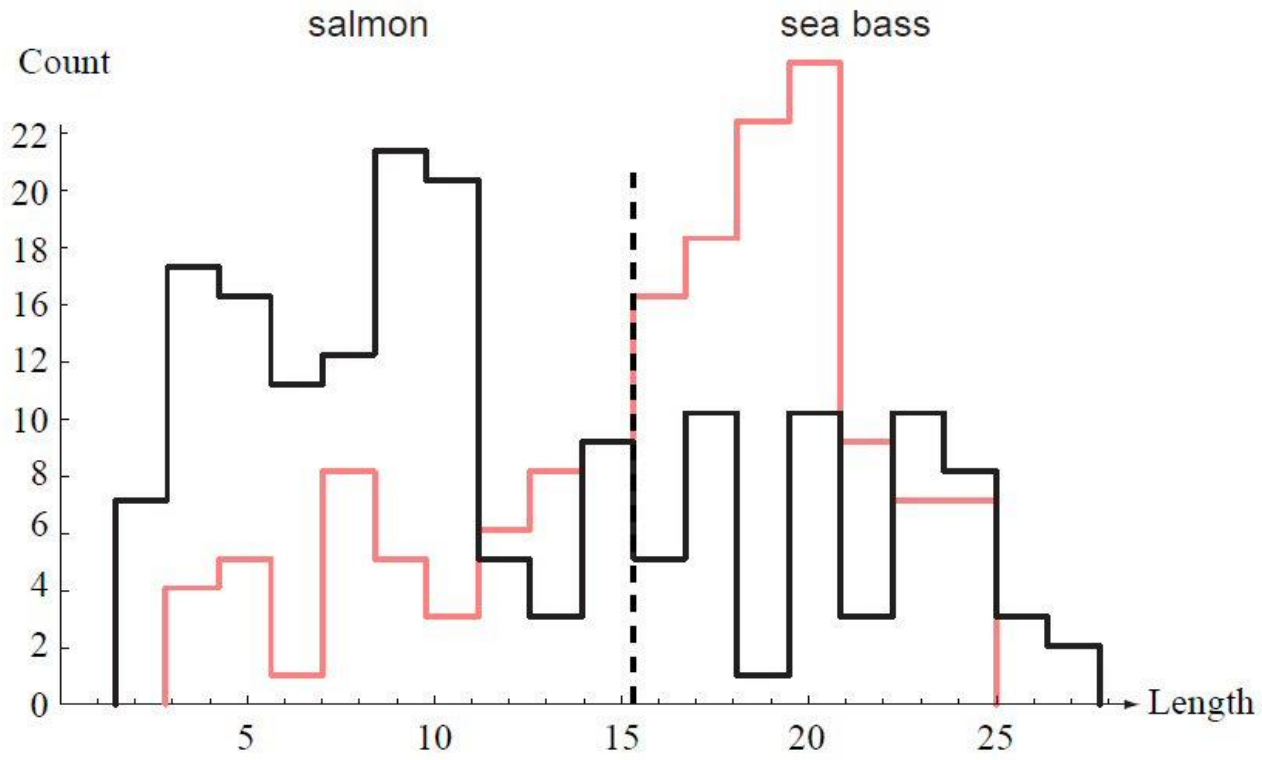
Salmon

Example: Automatic Fish-Packing Plant

- **Pre-processing**: apply a segmentation operation in order to isolate fishes from one another and from the background.
- **Feature extraction**: measure some features or properties from the image which will help in discriminating the two species of fish considered (e.g., fish length and width).
- **Classification**: evaluate the evidence presented and make a final decision as to the species.

Example: Automatic Fish-Packing Plant

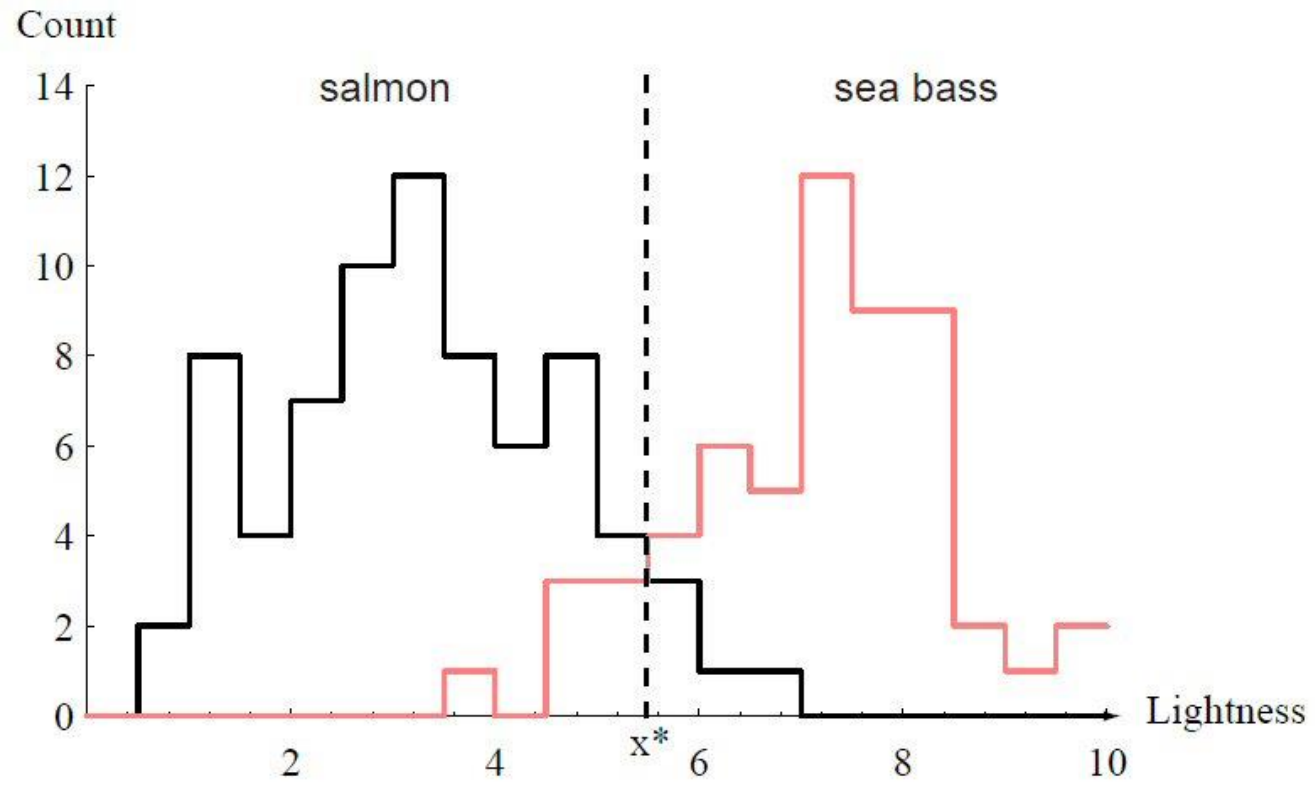
Classification Based on Length Feature



Using length appears not effective!

Example: Automatic Fish-Packing Plant

Classification Based on Lightness Feature

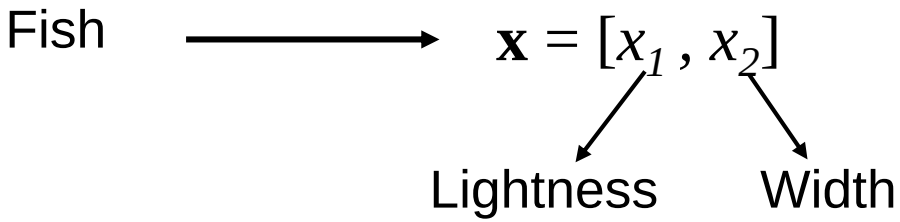


Looks better but still not enough satisfactory.

Example: Automatic Fish-Packing Plant

- In order to increase further the discrimination capability, one may think to adopt two features instead of just one.

- For instance, one could consider the width feature in addition to the lightness one:



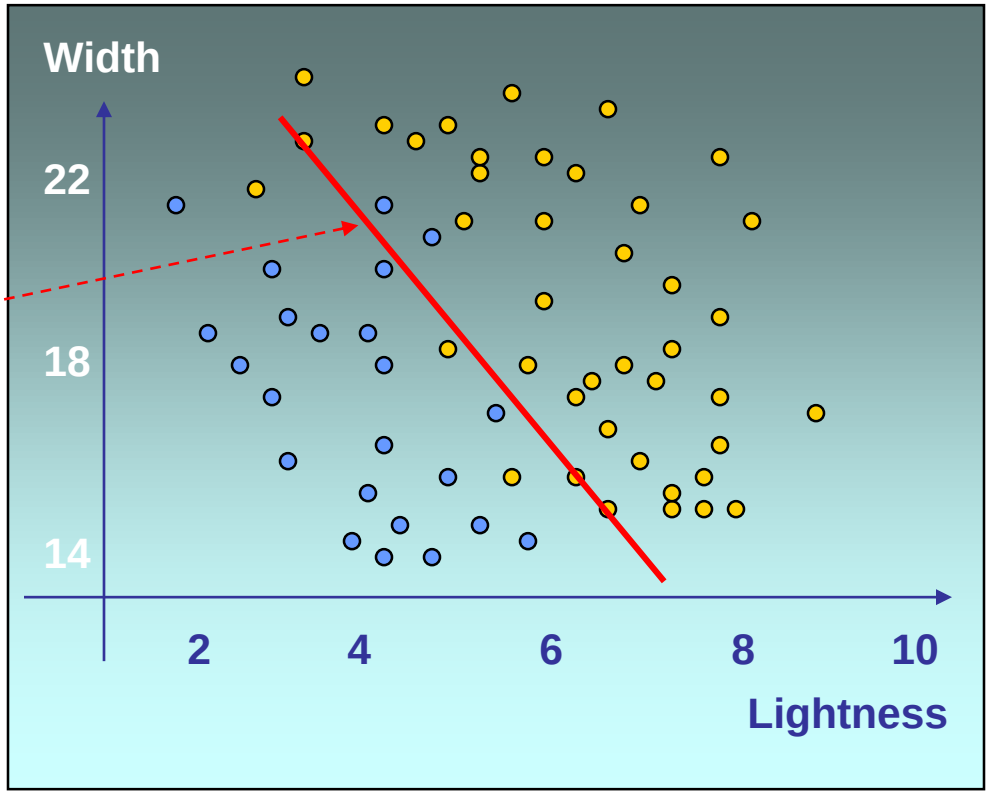
- **Problem** ⇒ we need to define:
  - classification model
  - cost function (e.g., minimize the number of errors)

- Let us first consider a linear classifier…

Example: Automatic Fish-Packing Plant

2D Feature Space – Linear Classifier

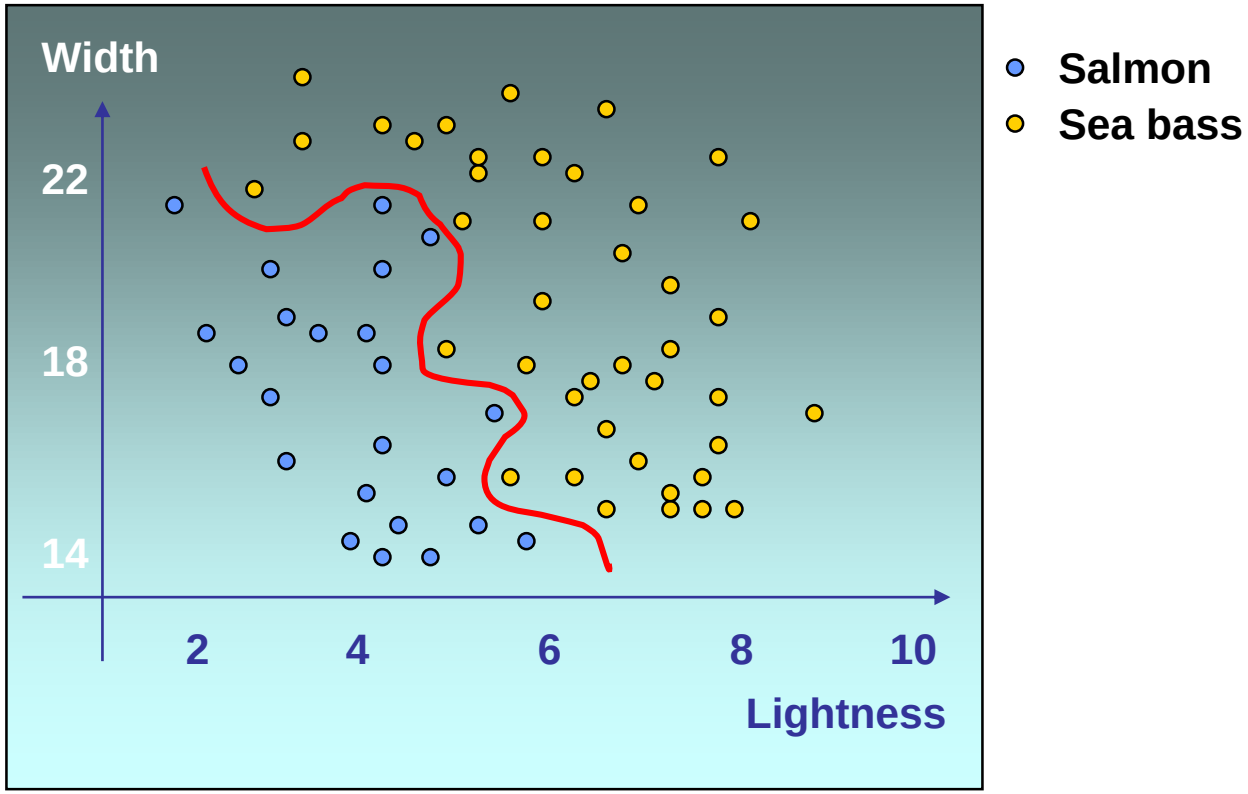
During the training phase, the classifier should estimate the best linear separation according to the adopted cost function.



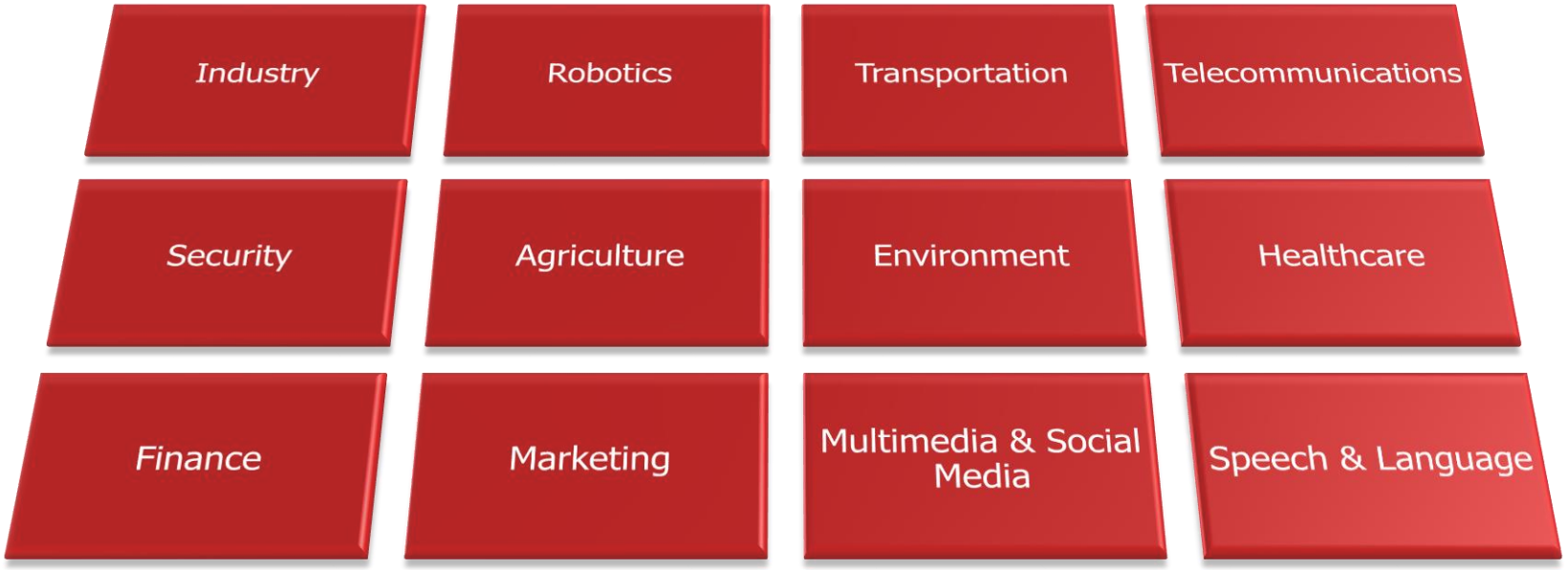
Example: Automatic Fish-Packing Plant

2D Feature Space – Highly Nonlinear Classifier

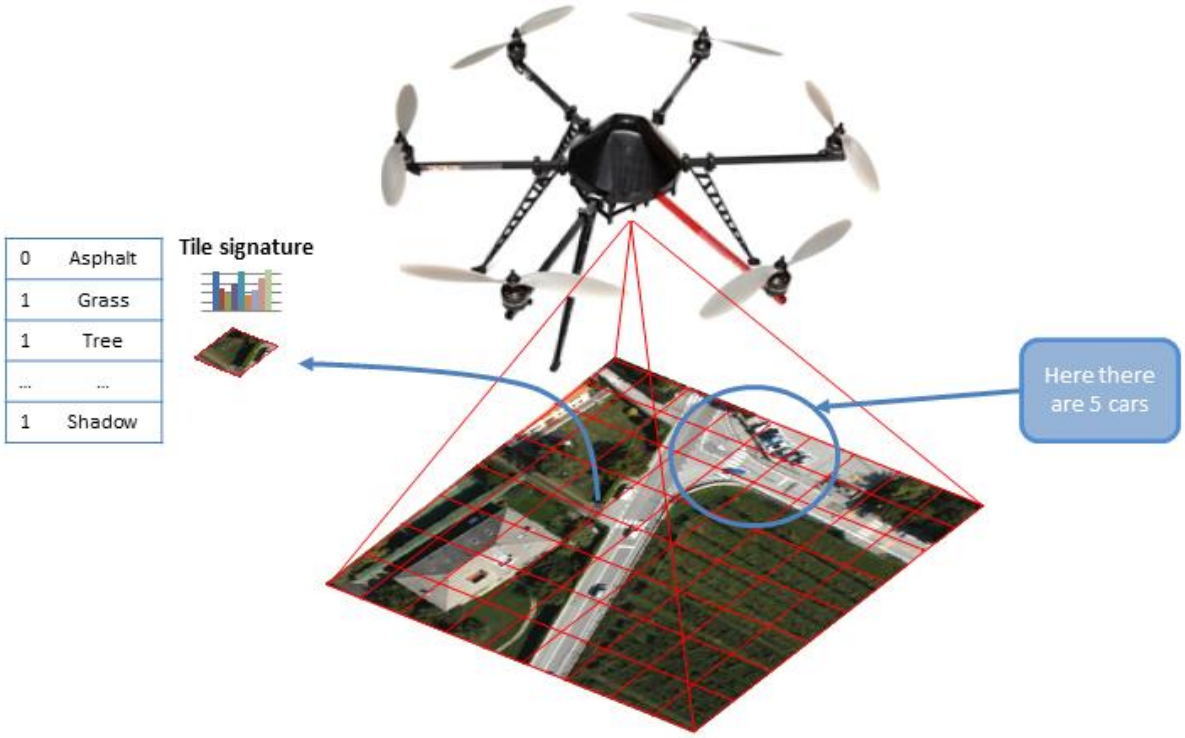
It is important to not tune excessively (overfit) the classifier on the training samples so that to leave room for a correct (at least satisfactory) classification of novel patterns (samples)!



Application Domains

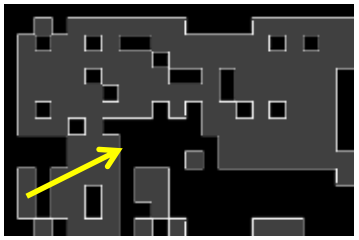


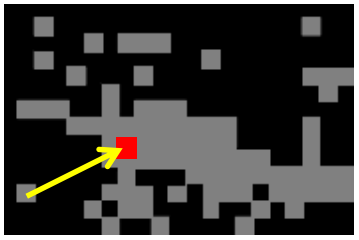
Example: UAV Image Analysis

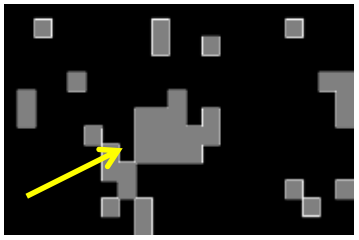


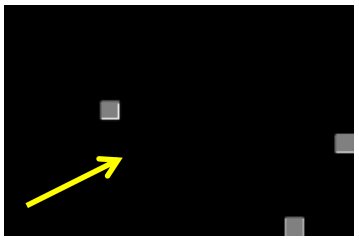
Example: UAV Image Analysis


Grass


Tree


Asphalt


Cars

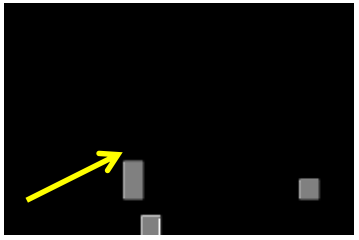

Solar Panel

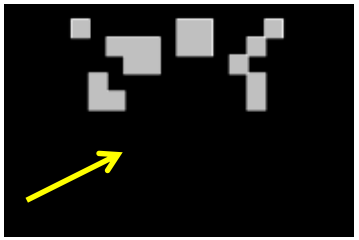

Vineyard

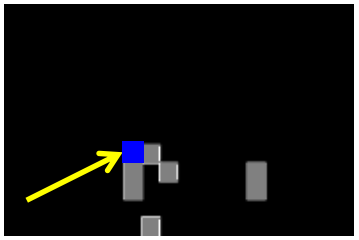

Roof1

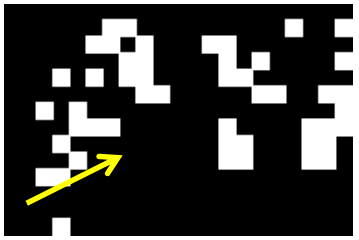

Roof2

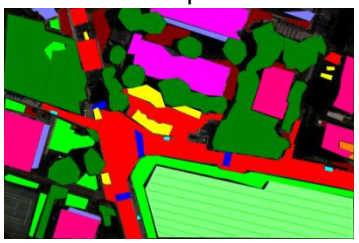

Soil

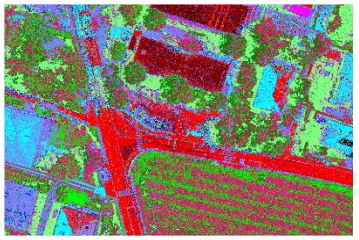

People

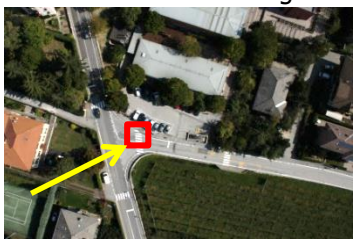

Building Facade


Pedestrian Crossing

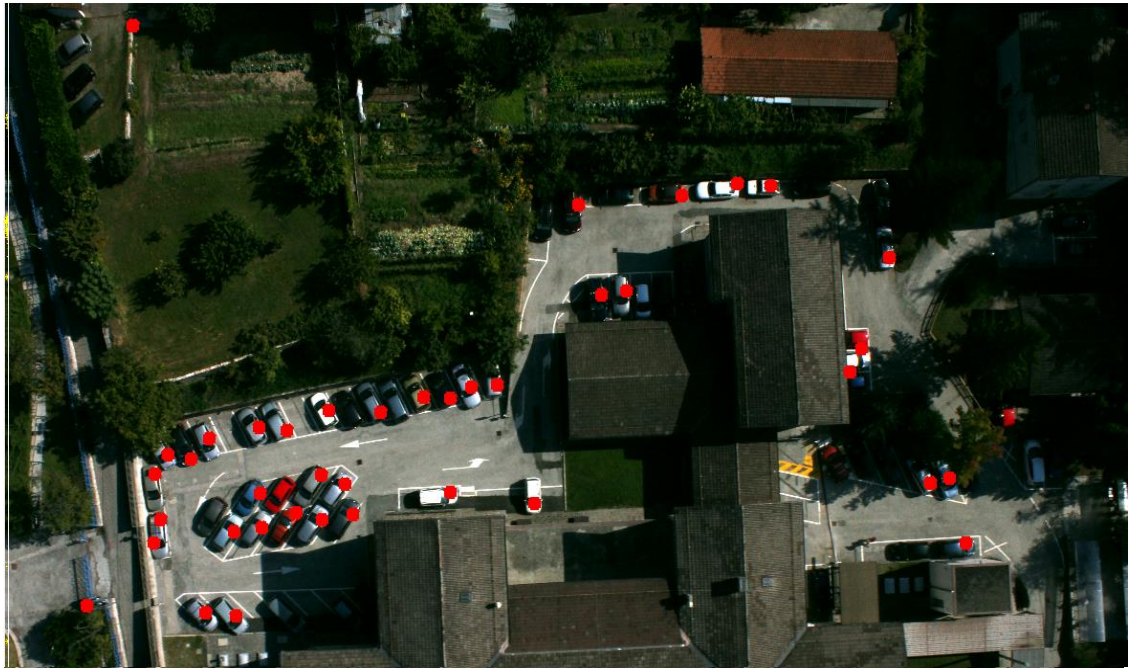

Shadow


Ground-Truth

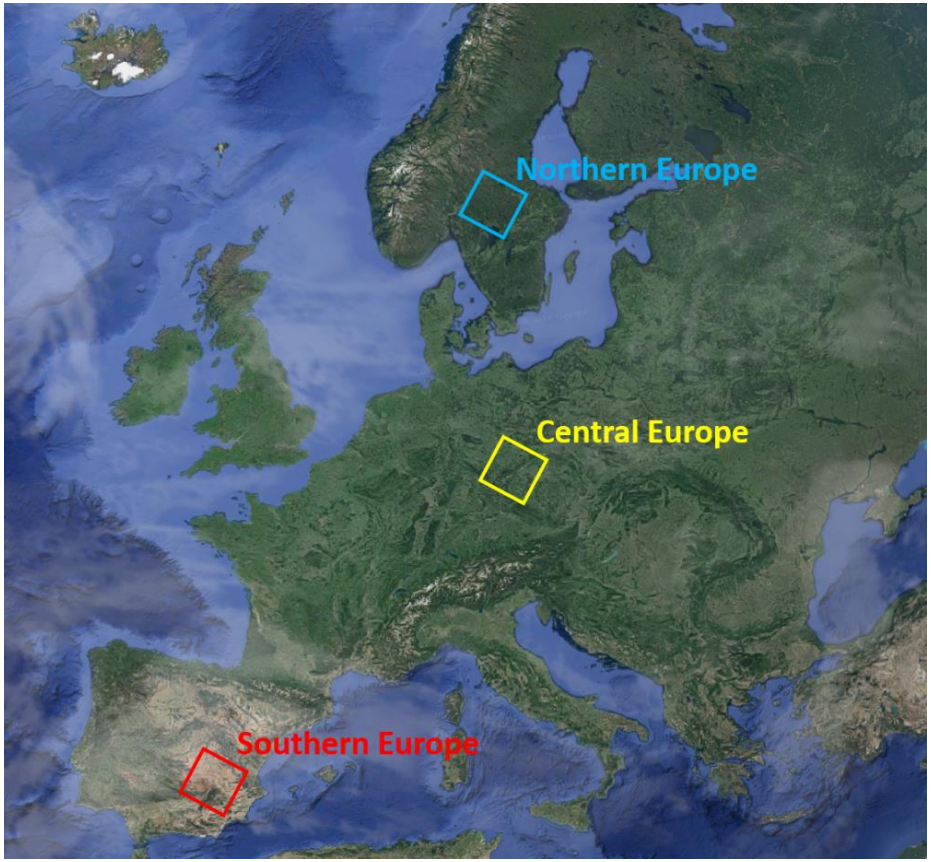

Pixel-based classification

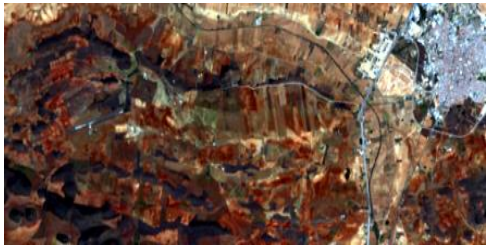

Original Image

Example: UAV Image Analysis

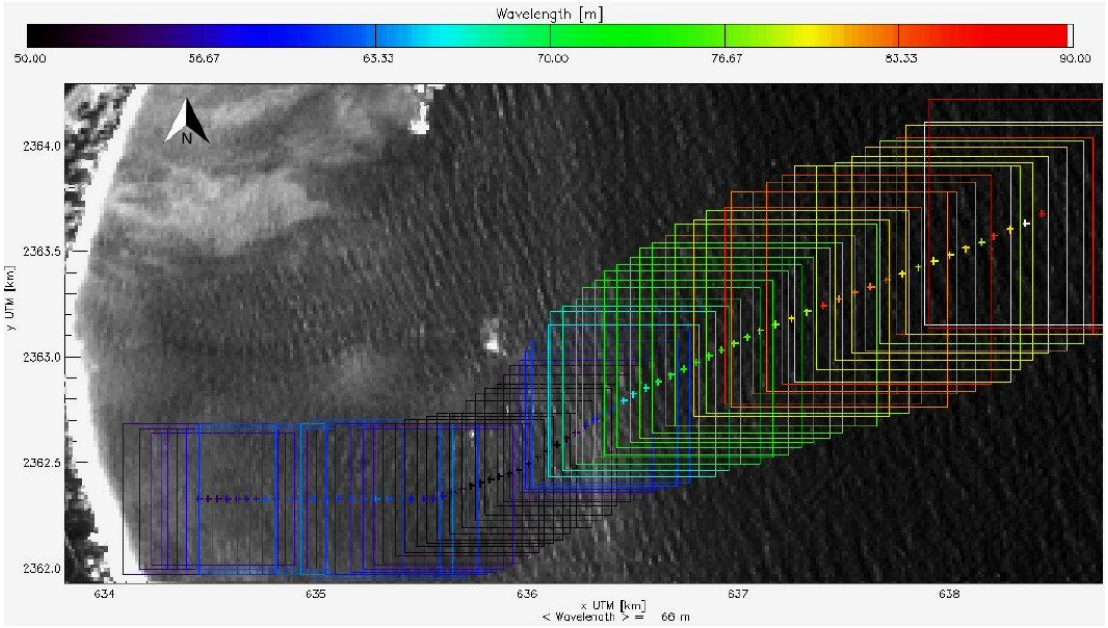


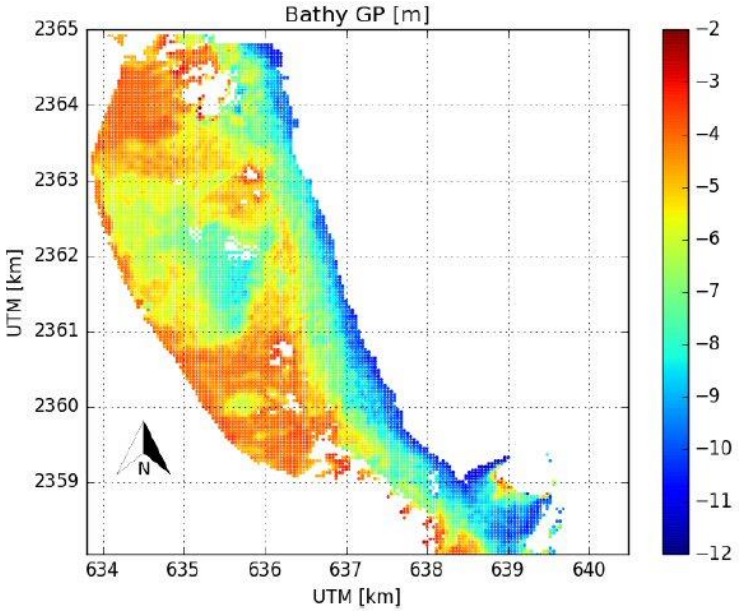
Example: Large Scale Mapping





Example: Bathymetry Mapping

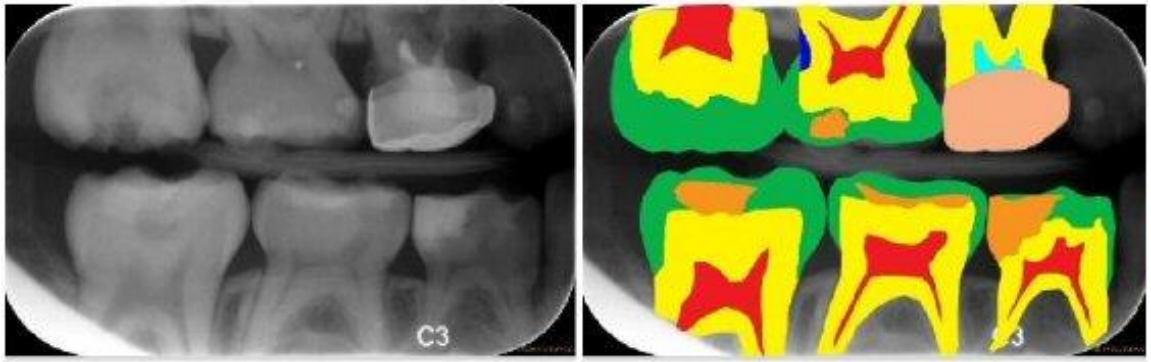




Example: Object Detection

Example: Event Recognition

Example: Semantic Segmentation



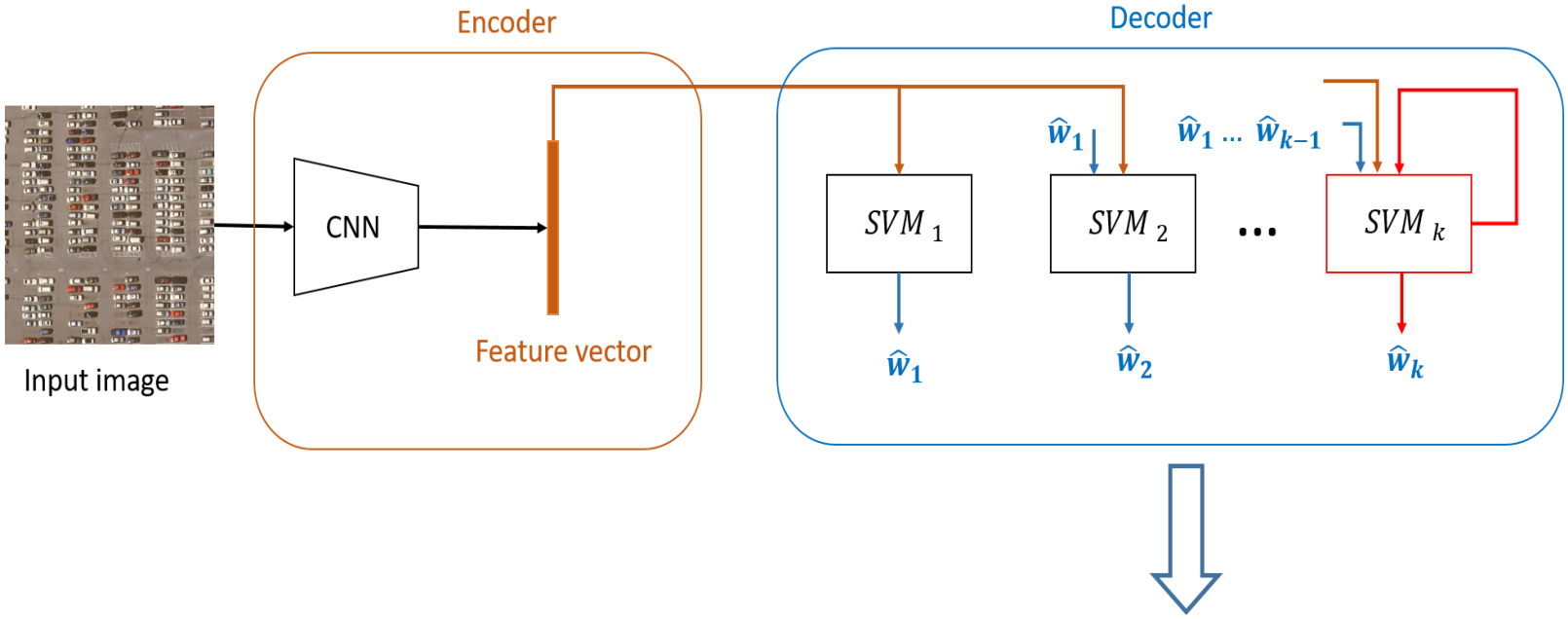
Example: Semantic Object Parsing





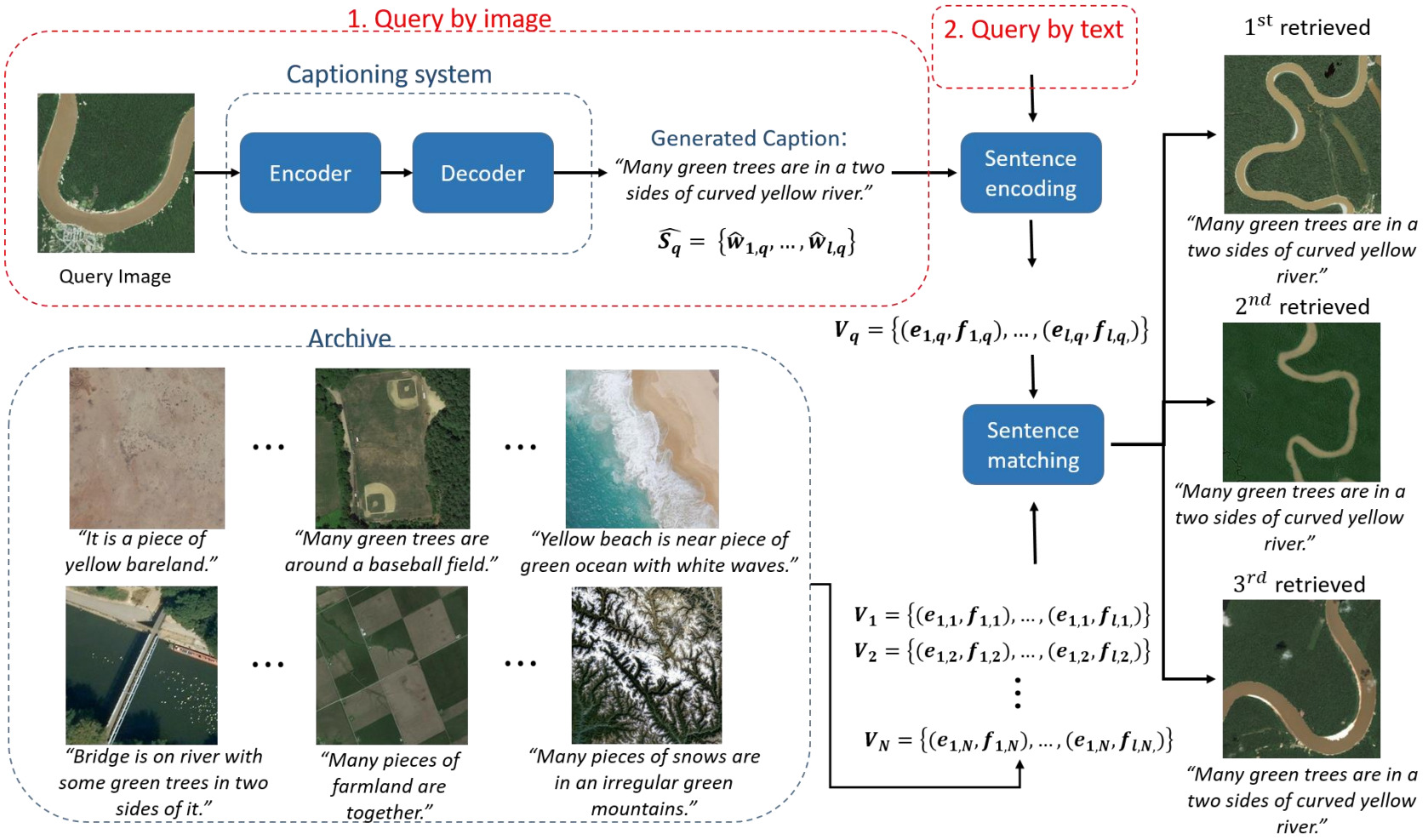



Example: Image Captioning



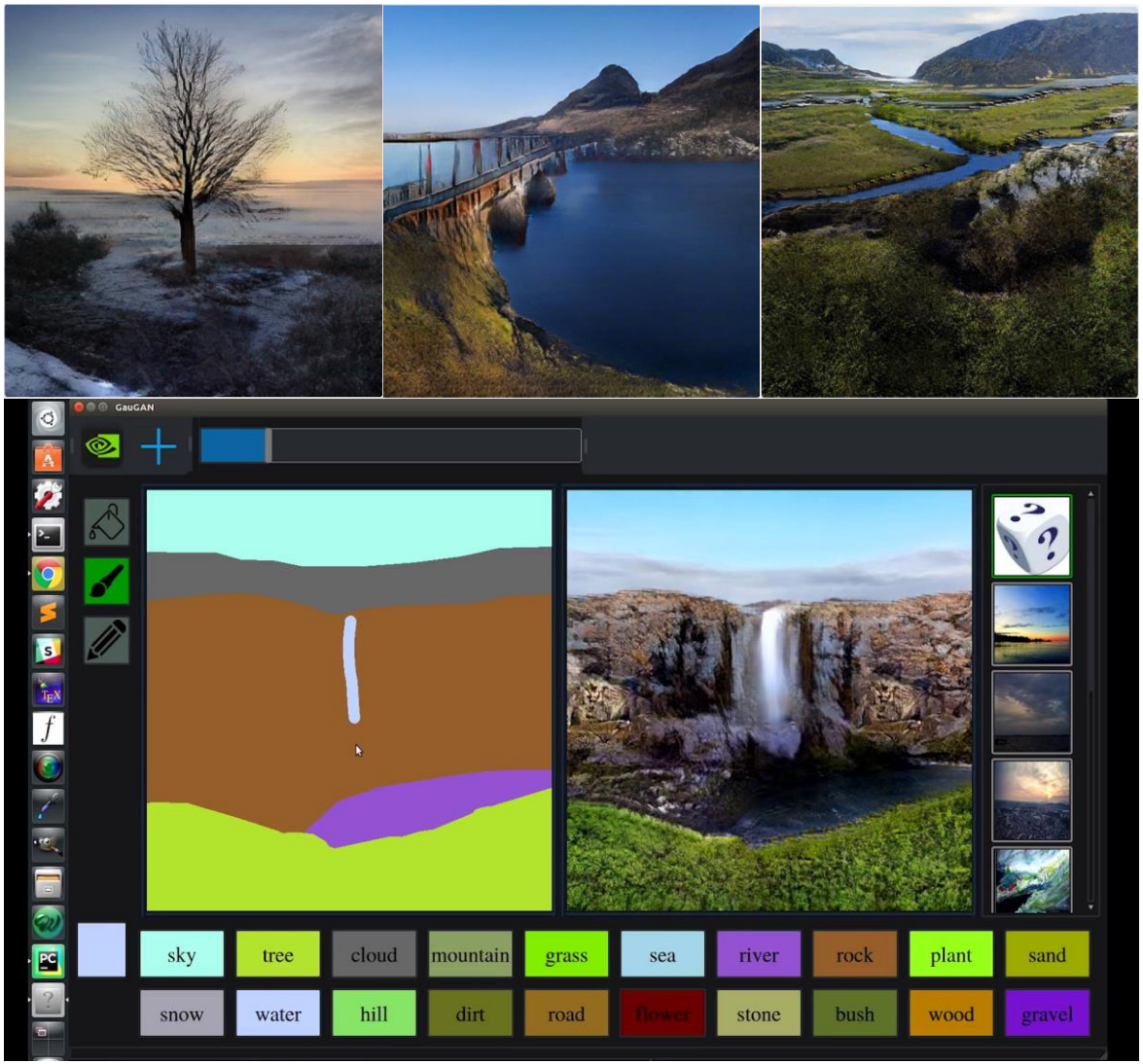
Generated description: Lots of cars parked closely with many empty parking spaces in the parking lot.

Example: Image Retrieval



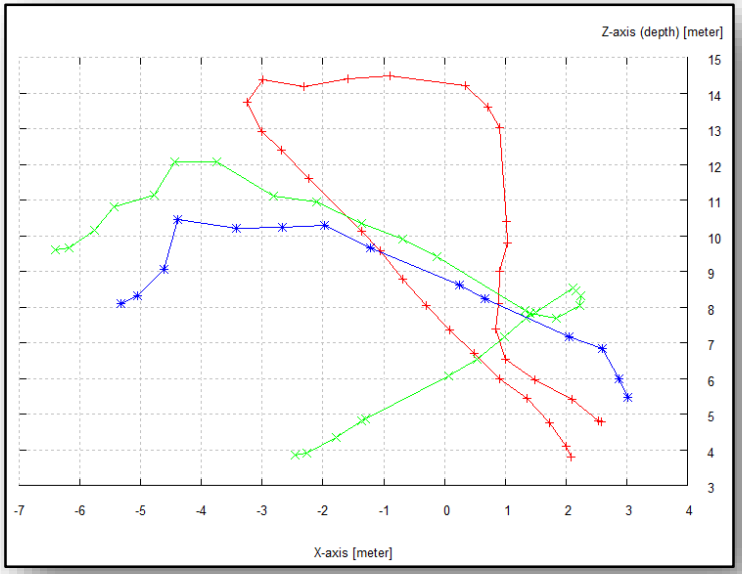
Example: Text-to-Image Synthesis

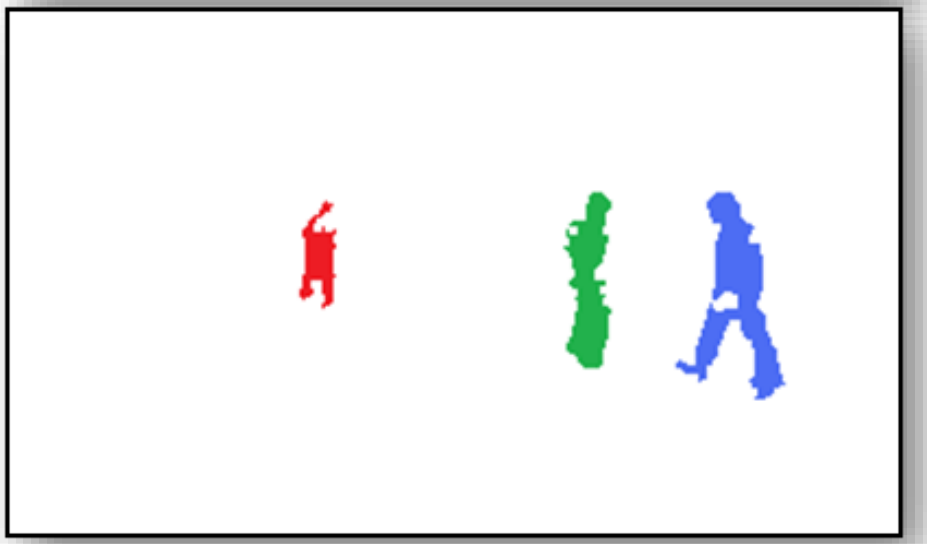
Example: Painting-to-Image Synthesis



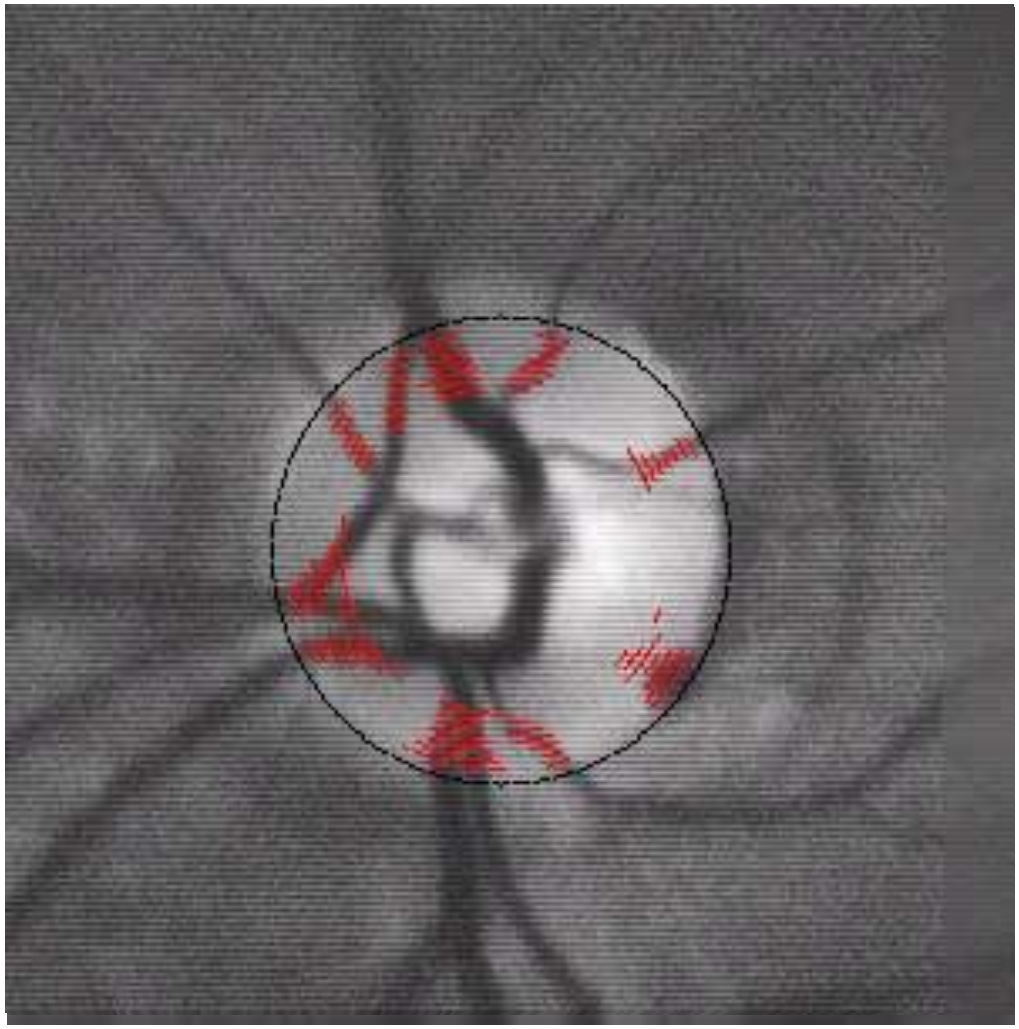
Example: Video Surveillance

- Multiple person tracking
- Behavioral Analysis

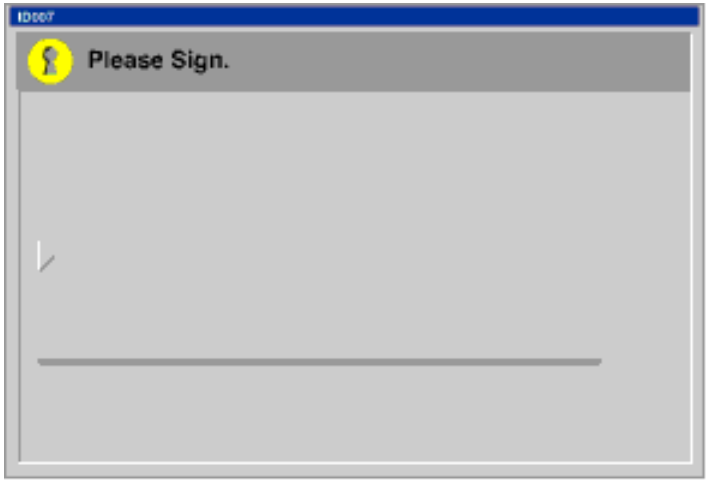




Example: Biometry

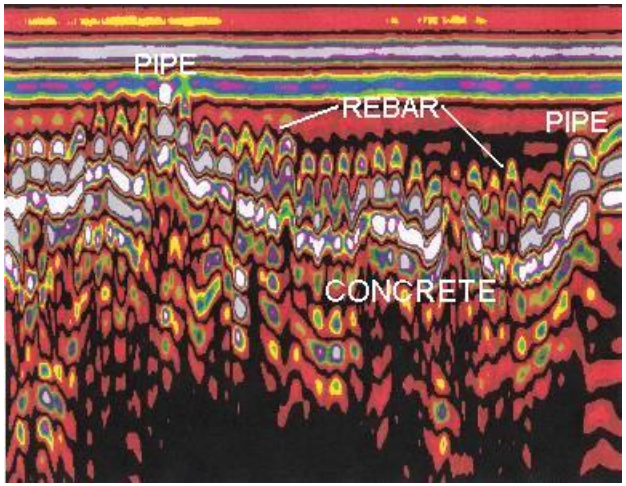


Example: Biometry

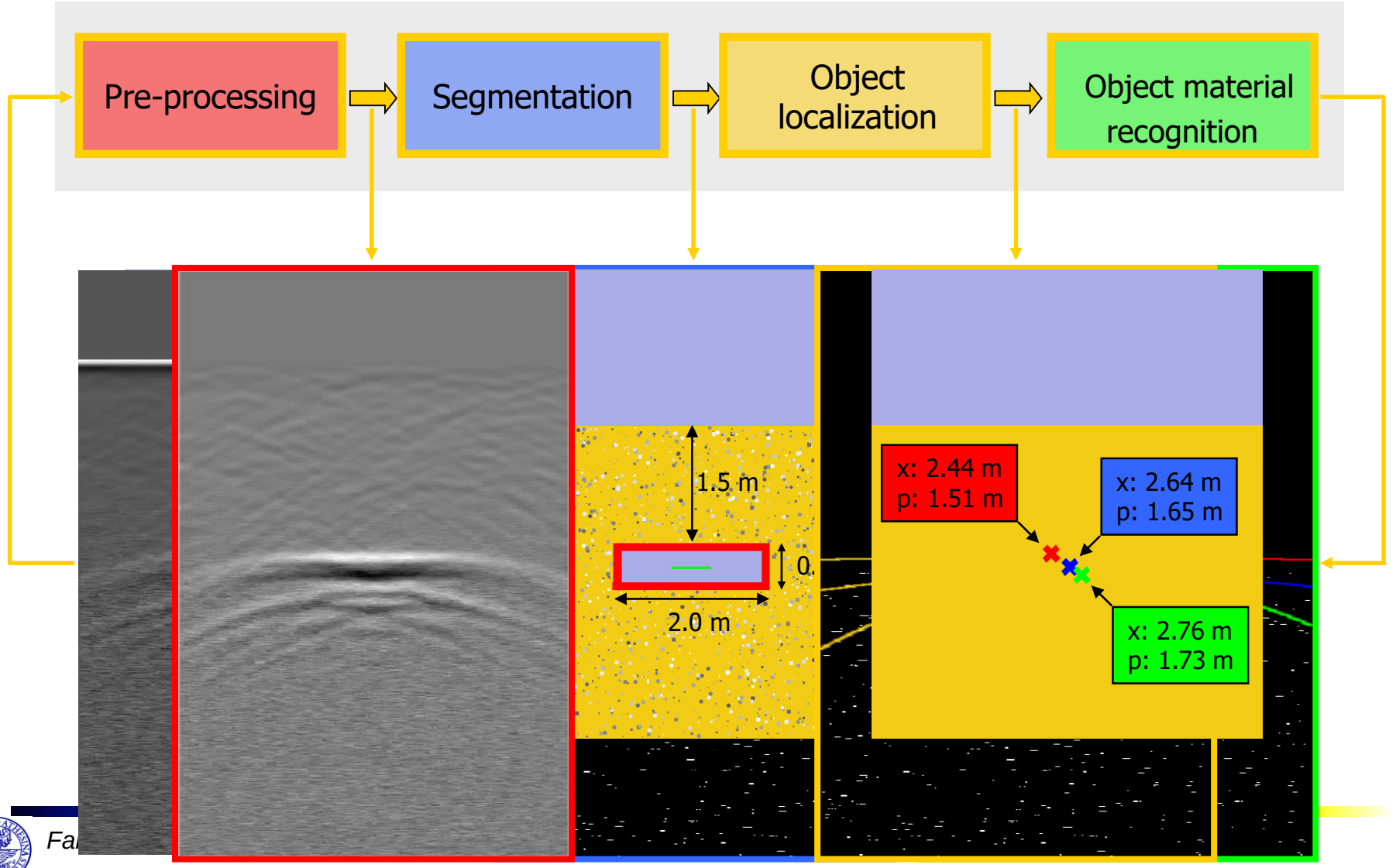


Example: Ground Penetrating Radar

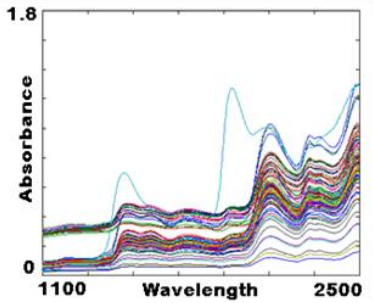
- Underground Storage Tanks
- Concrete Inspection
- Landfills and Burial Trenches
- Archaeological Studies
- Underground Structures

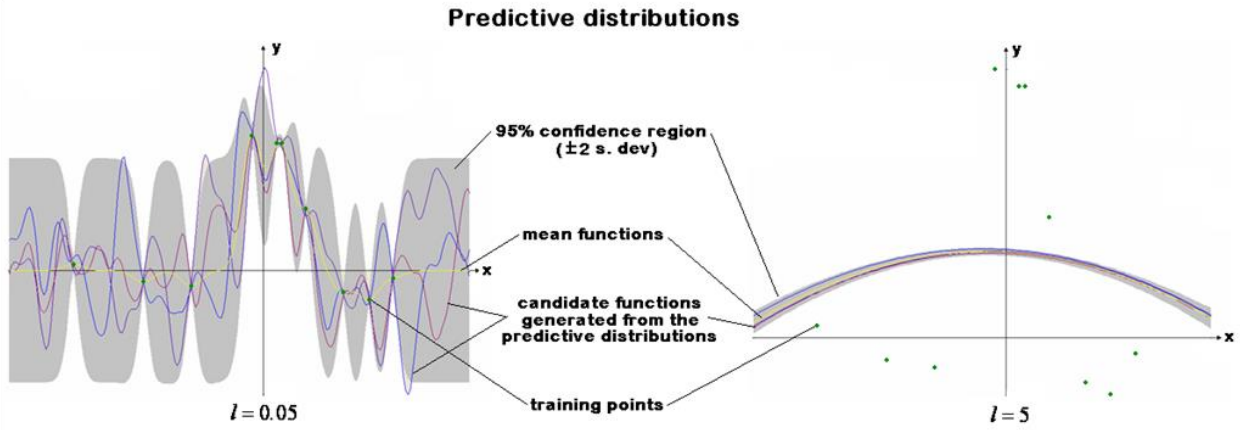


Example: Ground Penetrating Radar

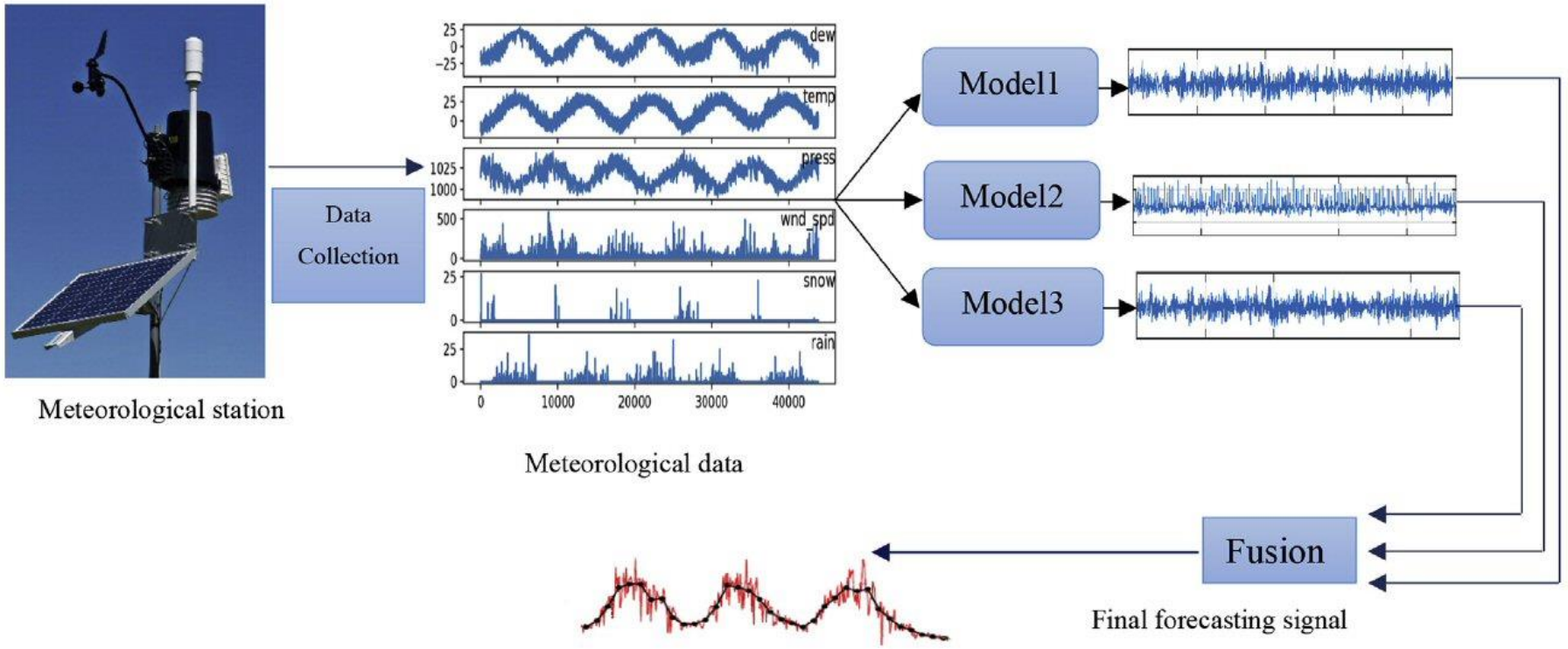


Example: Chemometric Data Analysis

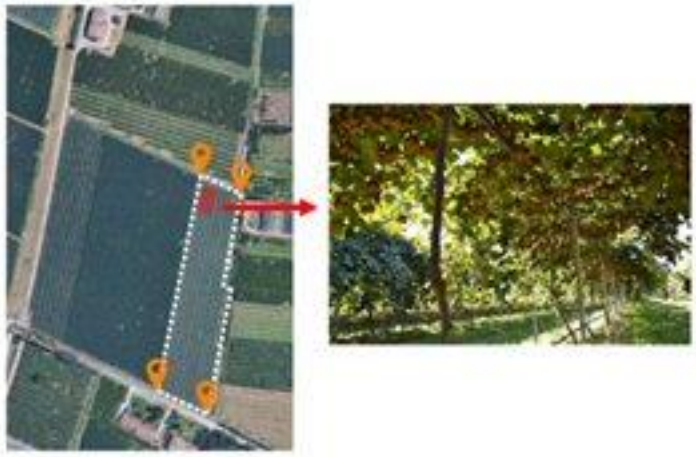




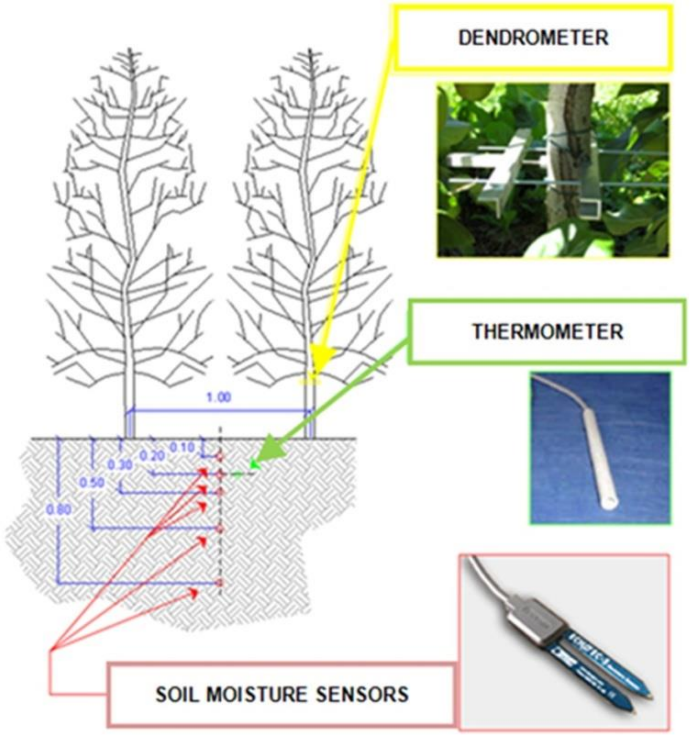
Example: Solar Radiation Forecasting



Example: Agriculture



Example: WSN-based Environmental Monitoring



Unknowns:

Real-Time Evolution of Environmental Phenomena

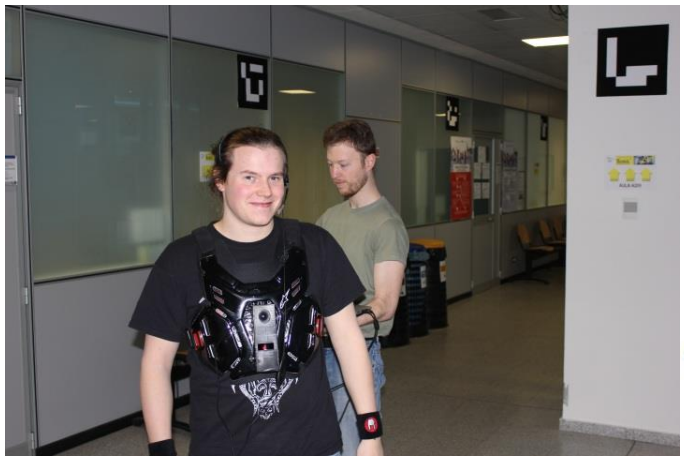
Data:

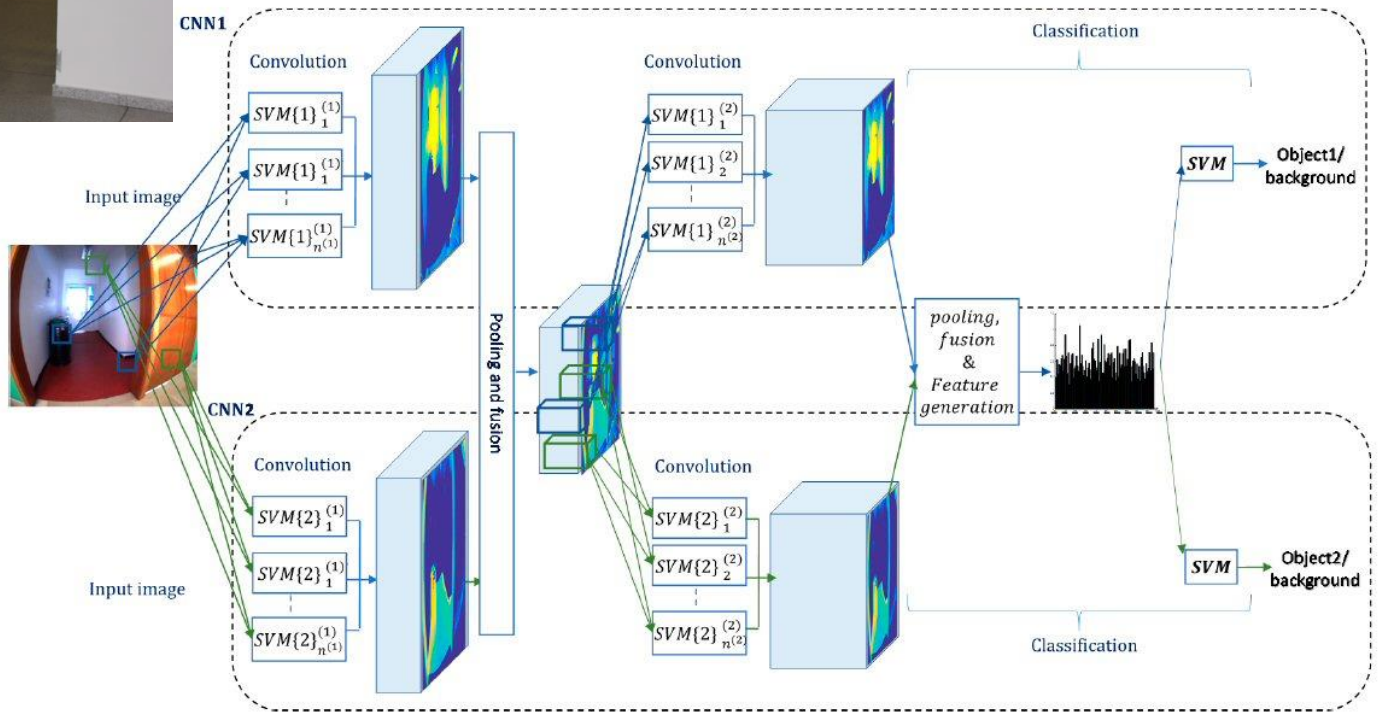
Light, Humidity, Temperature, EM Field Level, etc.

Applications:

Precision Farming, Pollution Control, EM Interferences

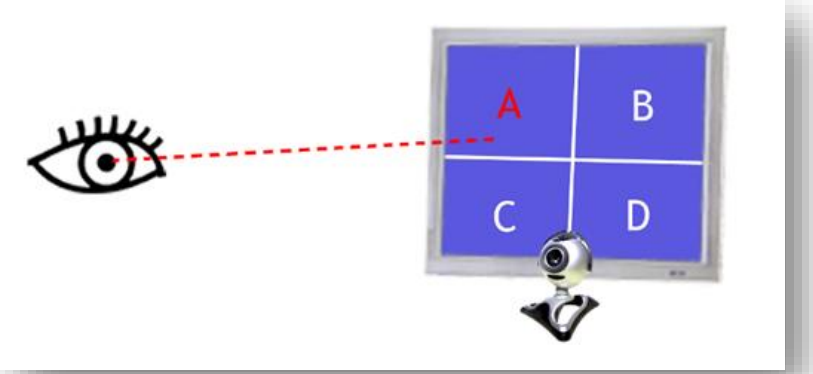
Example: Assistive Technologies

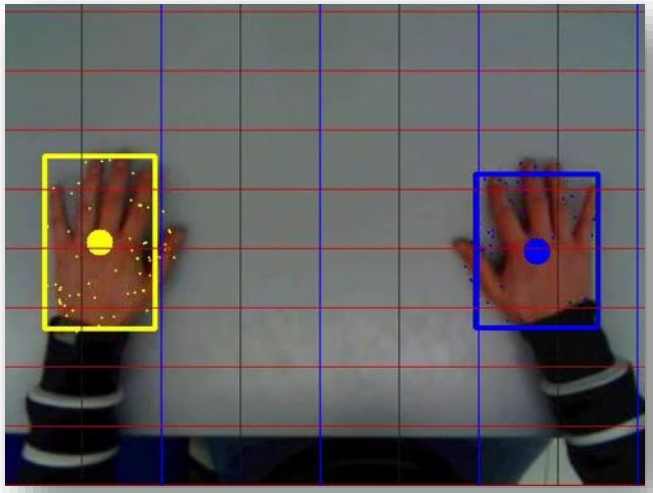




Example: Assistive Technologies

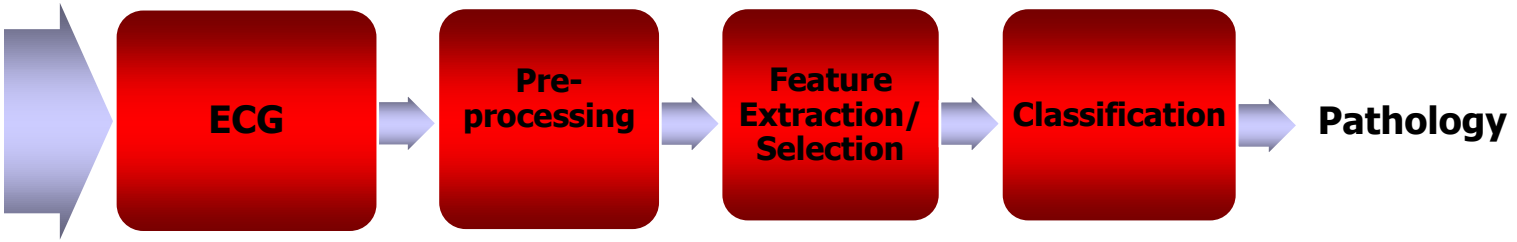
Enhanced human machine interfaces through gesture recognition and eye tracking



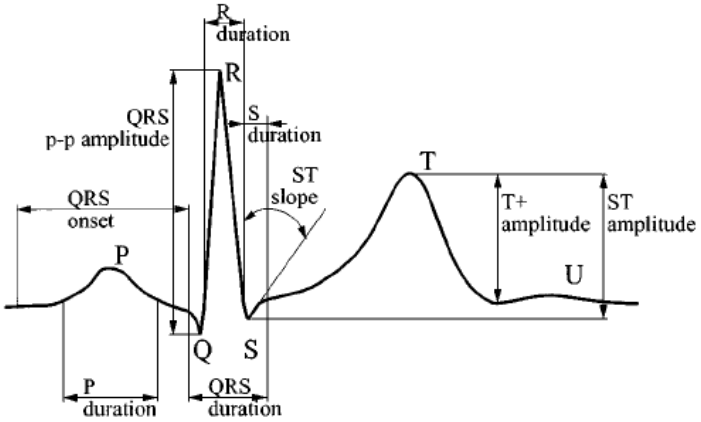


Example: Cardiac Pathology Detection

Heart

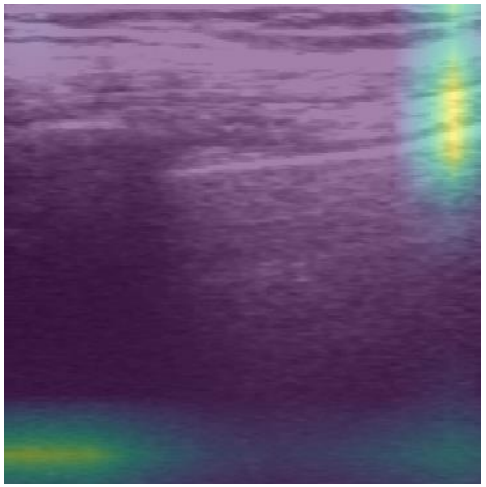


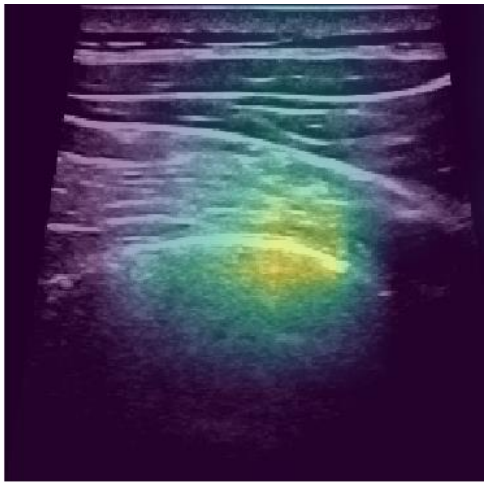
ECG signal



Example: COVID-19 Detection

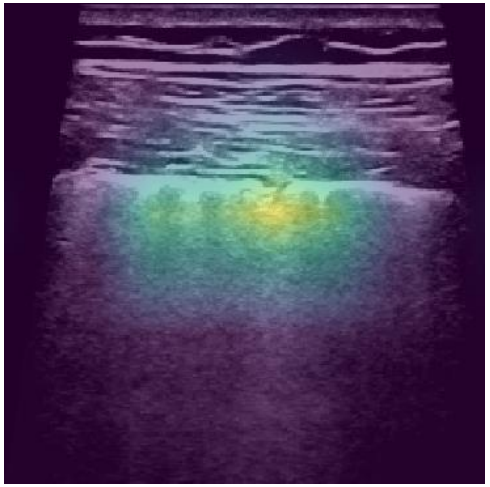
Case 0

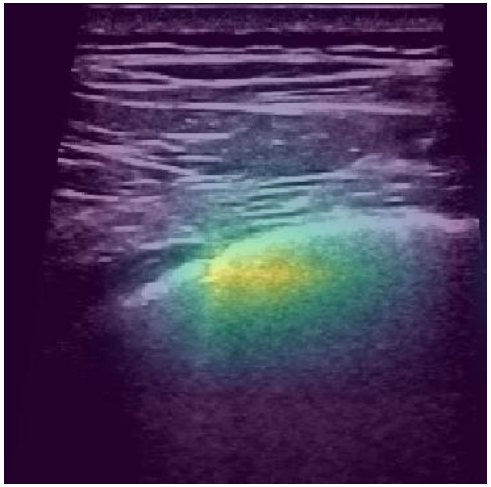




Case 1

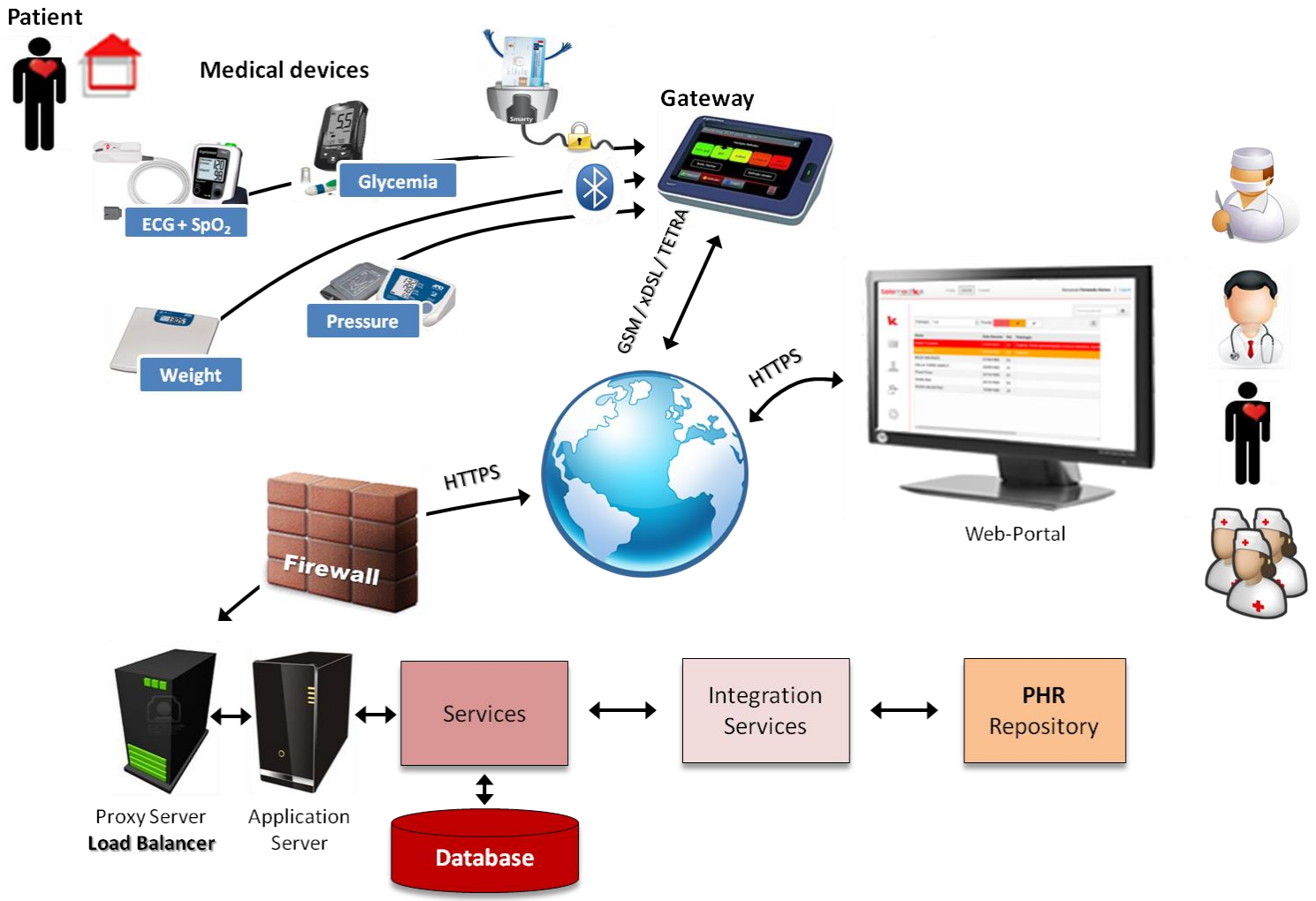
Case 2





Case 3

Example: Telemonitoring



Example: DNA Microarray Image Analysis