An introduction to pattern recognition and clustering

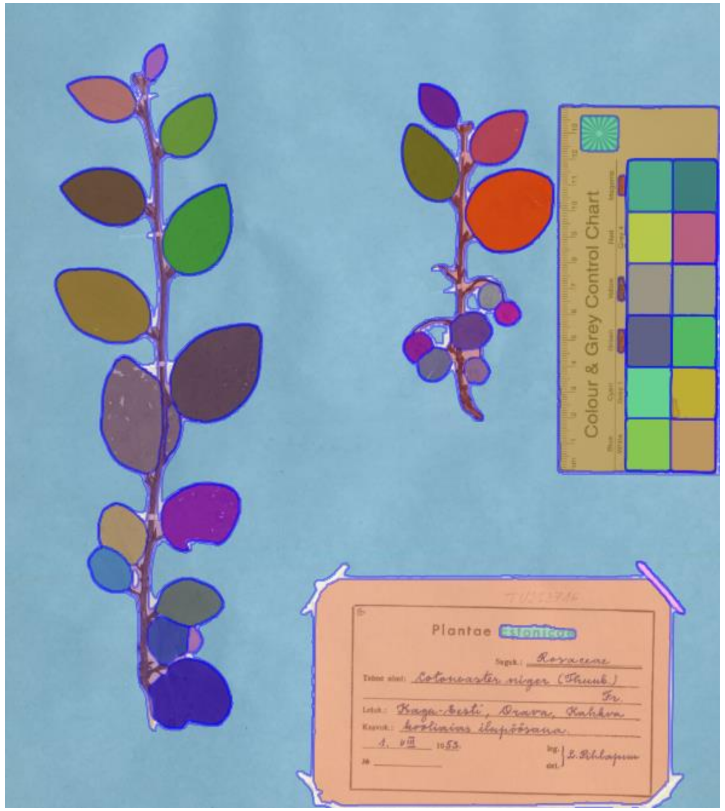
Lecture materials available on GitHub:

https://github.com/mluerig/jena_clustering_lecture

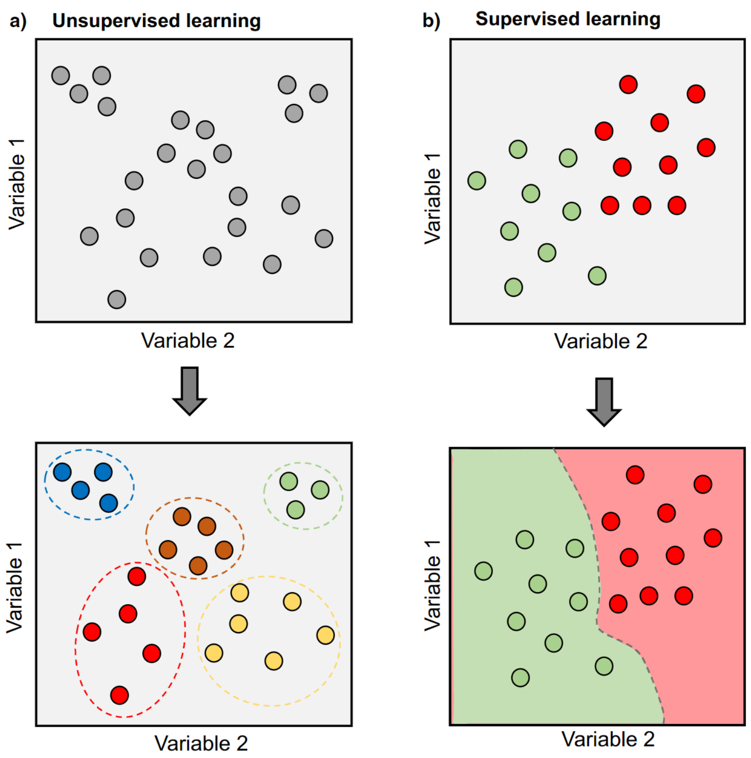
(scan this to experience an example of pattern recognition!)

Test lecture, Moritz Lürig – Jena, 2024-04-25

An introduction to pattern recognition and clustering



Part 1: Computer vision



Part 2: Clustering

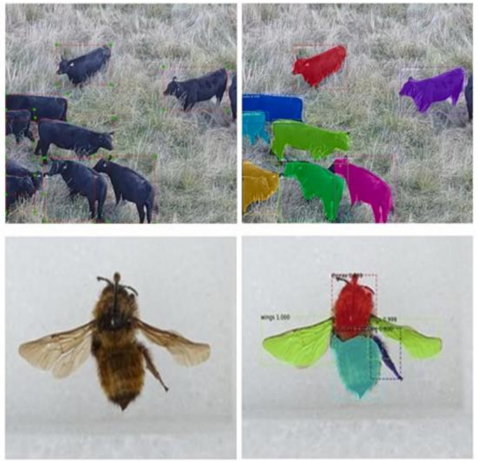
Test lecture, Moritz Lürig – Jena, 2024-04-25

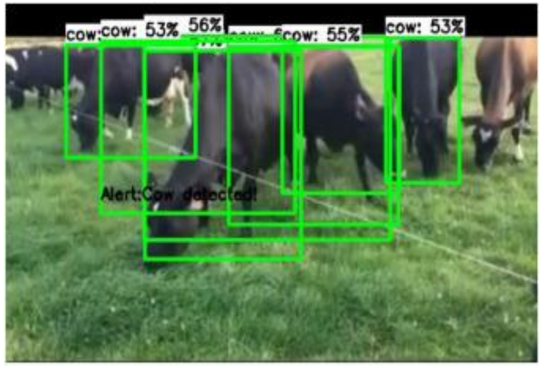
Automated image analysis

External phenotypes and morphology, unlike internal phenotypes or DNA, are physical properties that can be captured and analyzed using digital imaging.

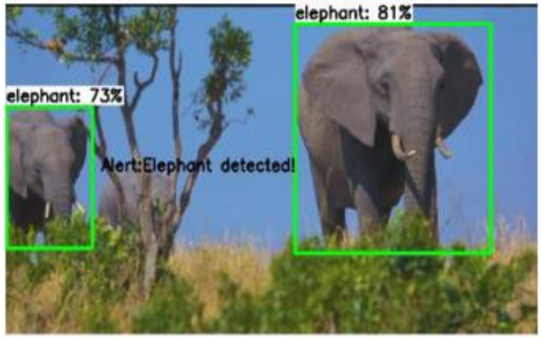
Computer vision, is an effective toolbox to extract meaningful features from images, and thereby facilitating, for example, the automated measurement of traits.

Especially if we are interested in measuring morphology in many specimens, modern, AI-based CV is indispensable

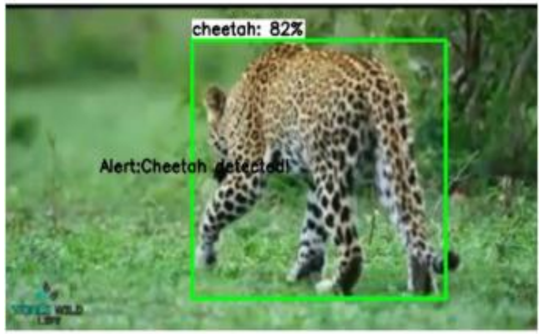




(a)



(b)

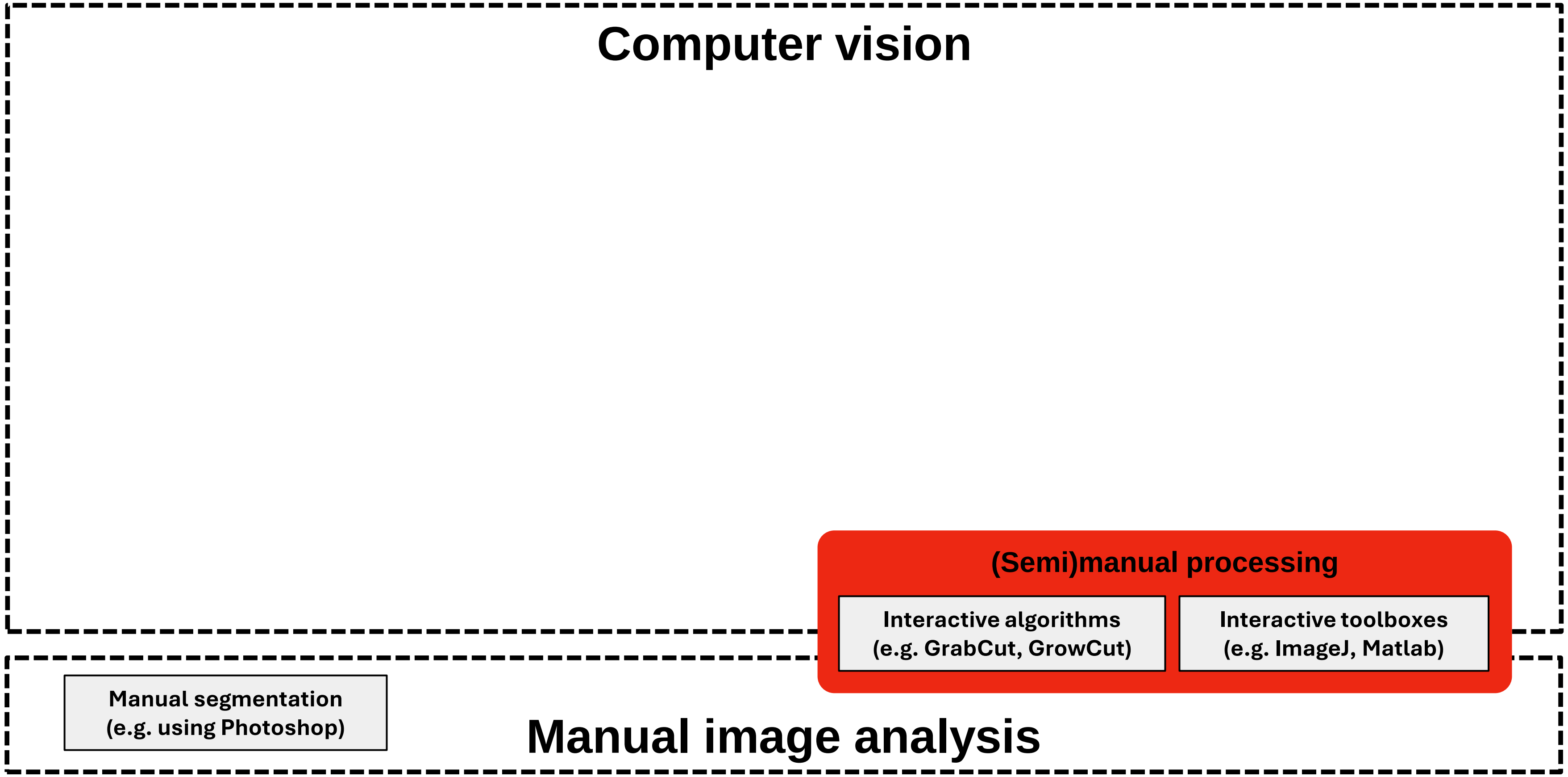


(c)

Introduction: Computer vision

Computer vision

A field at the intersection of machine learning and signal processing



Lürig et al. 2021

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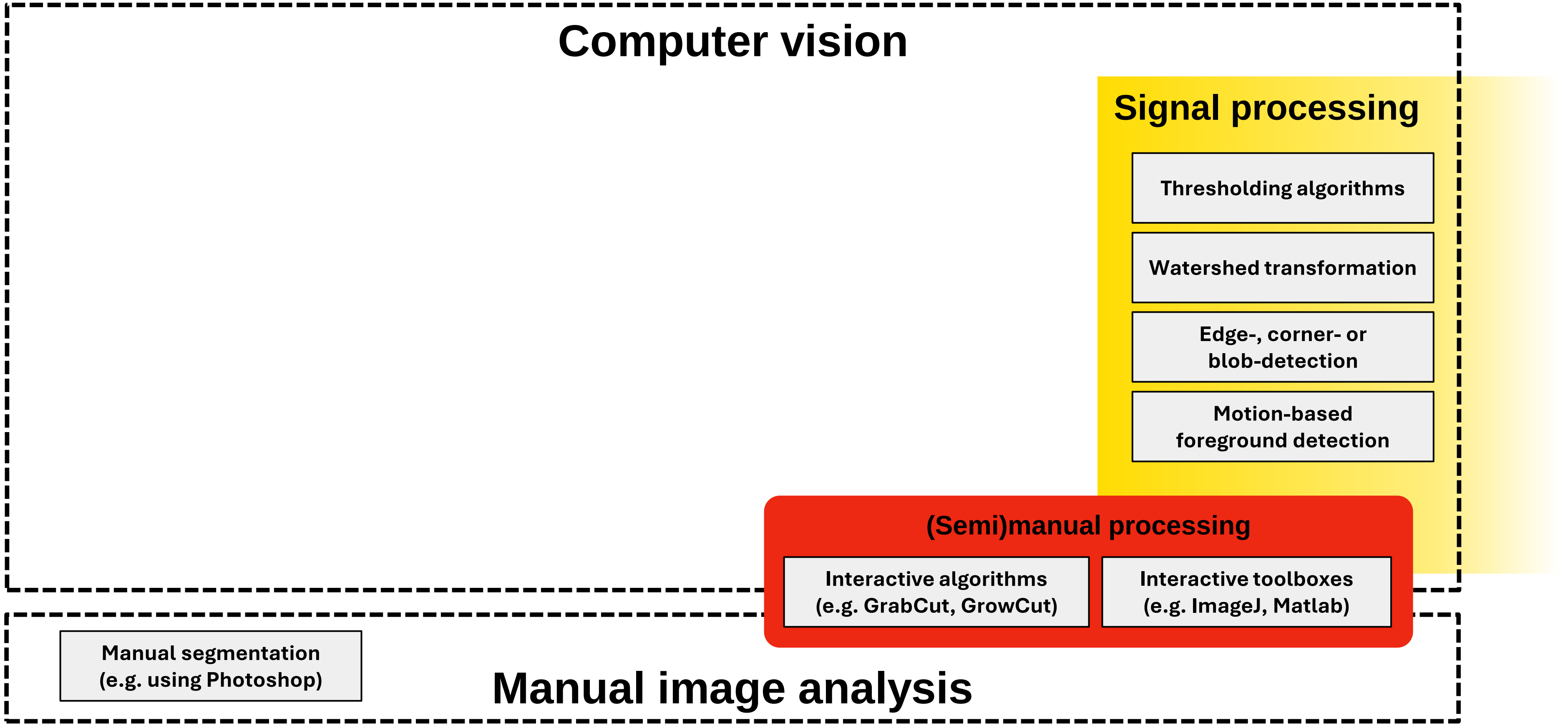

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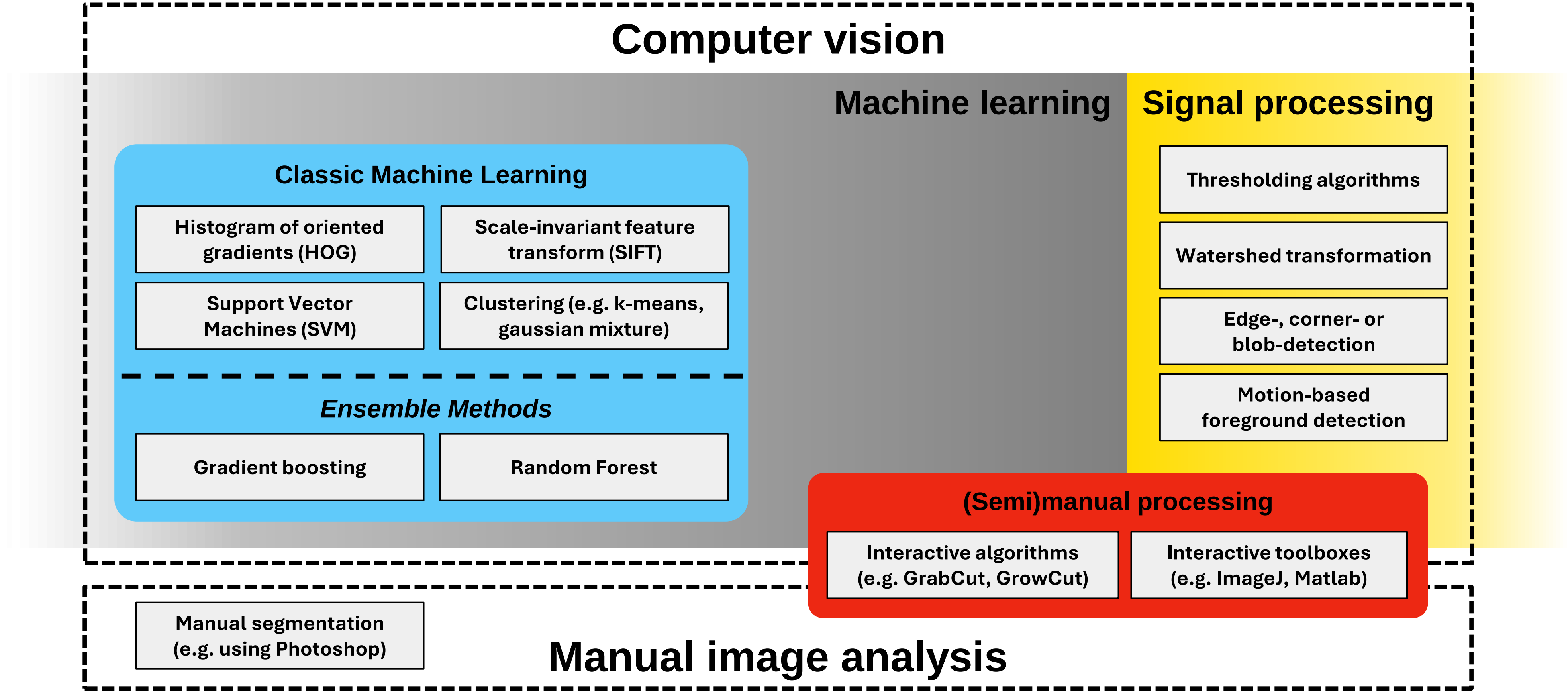

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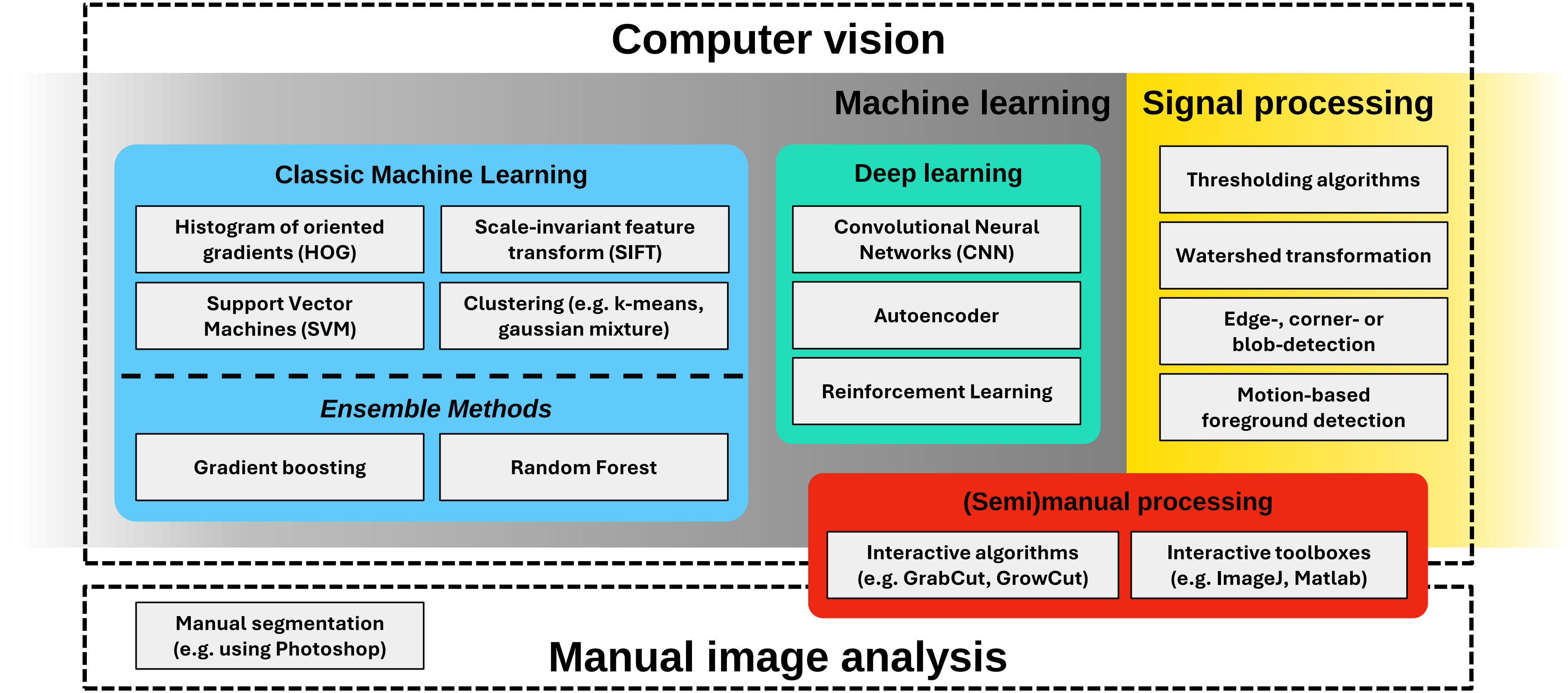

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Introduction: Computer vision

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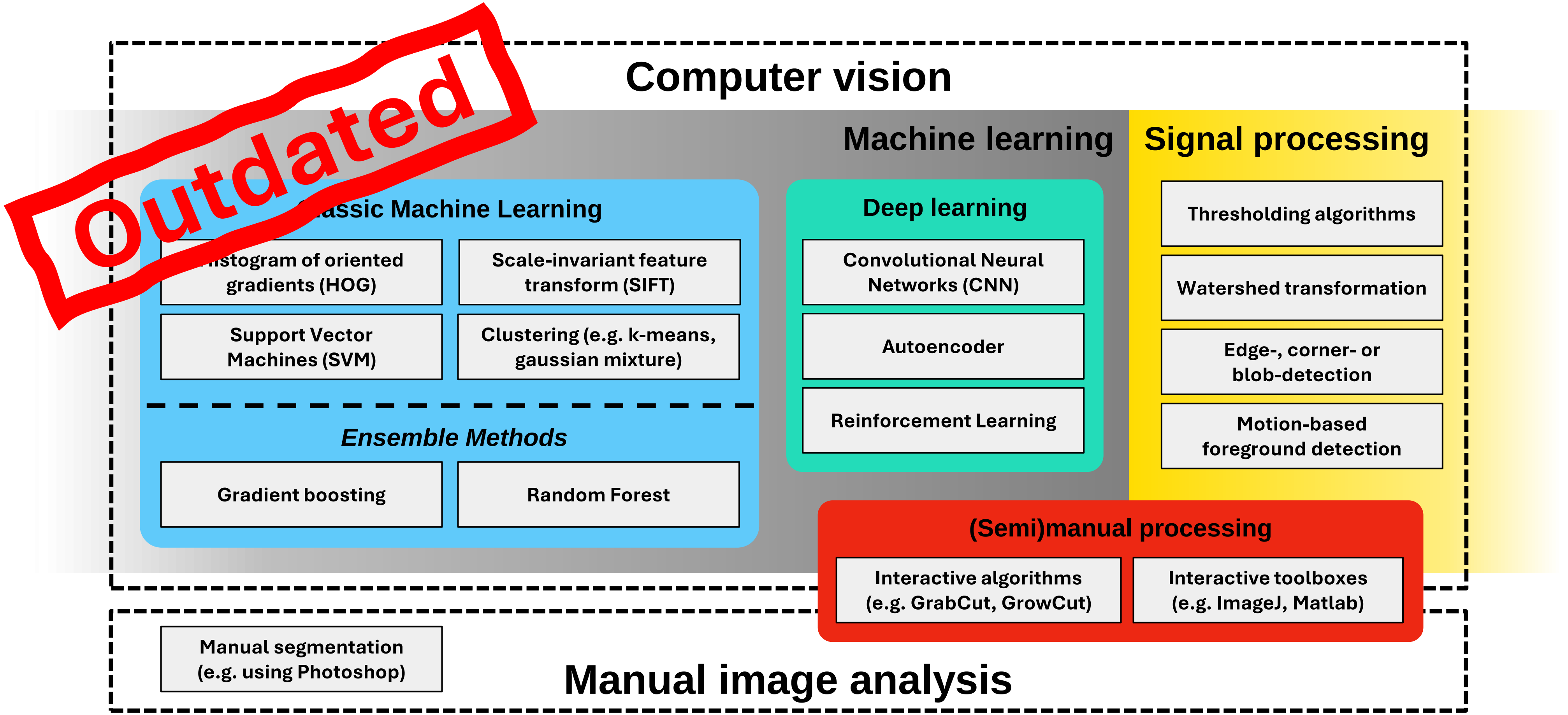

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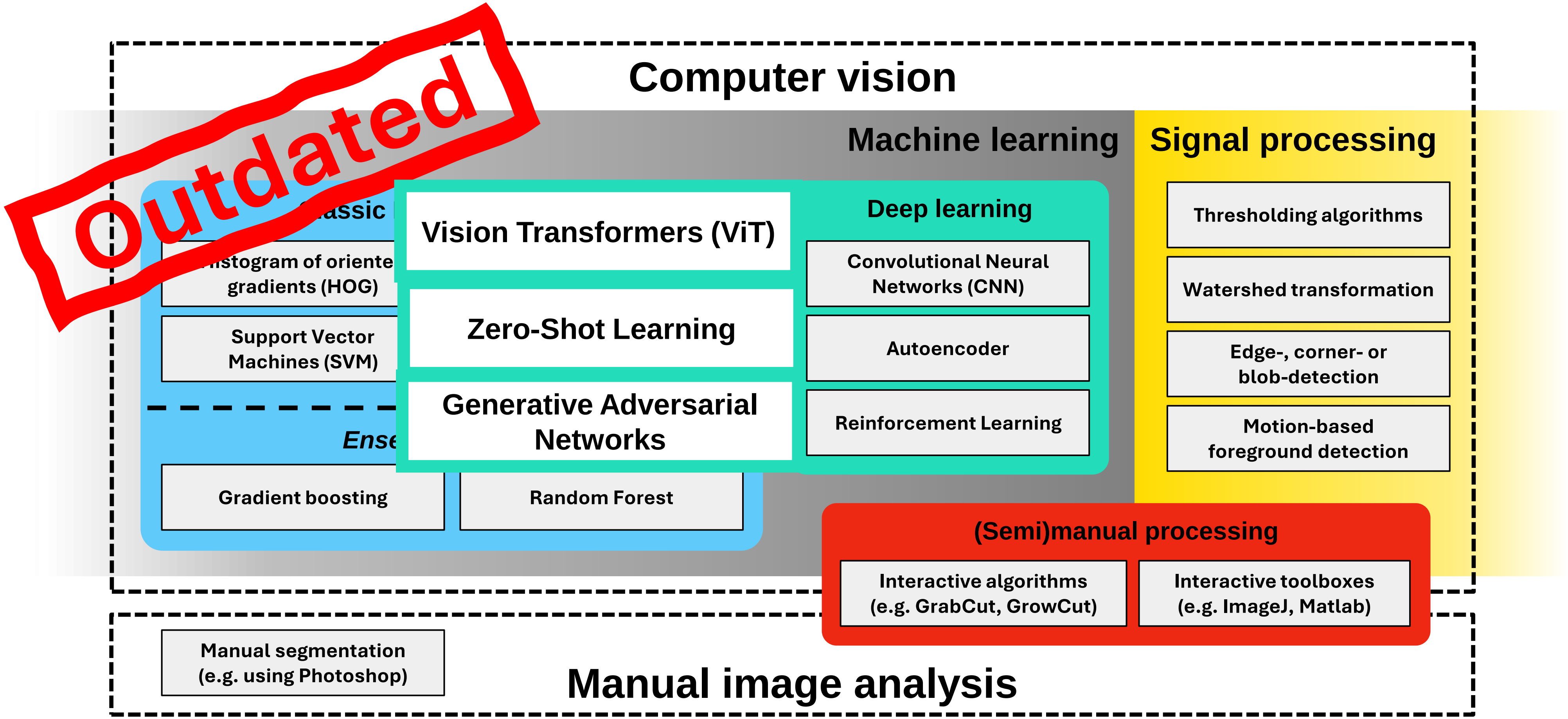

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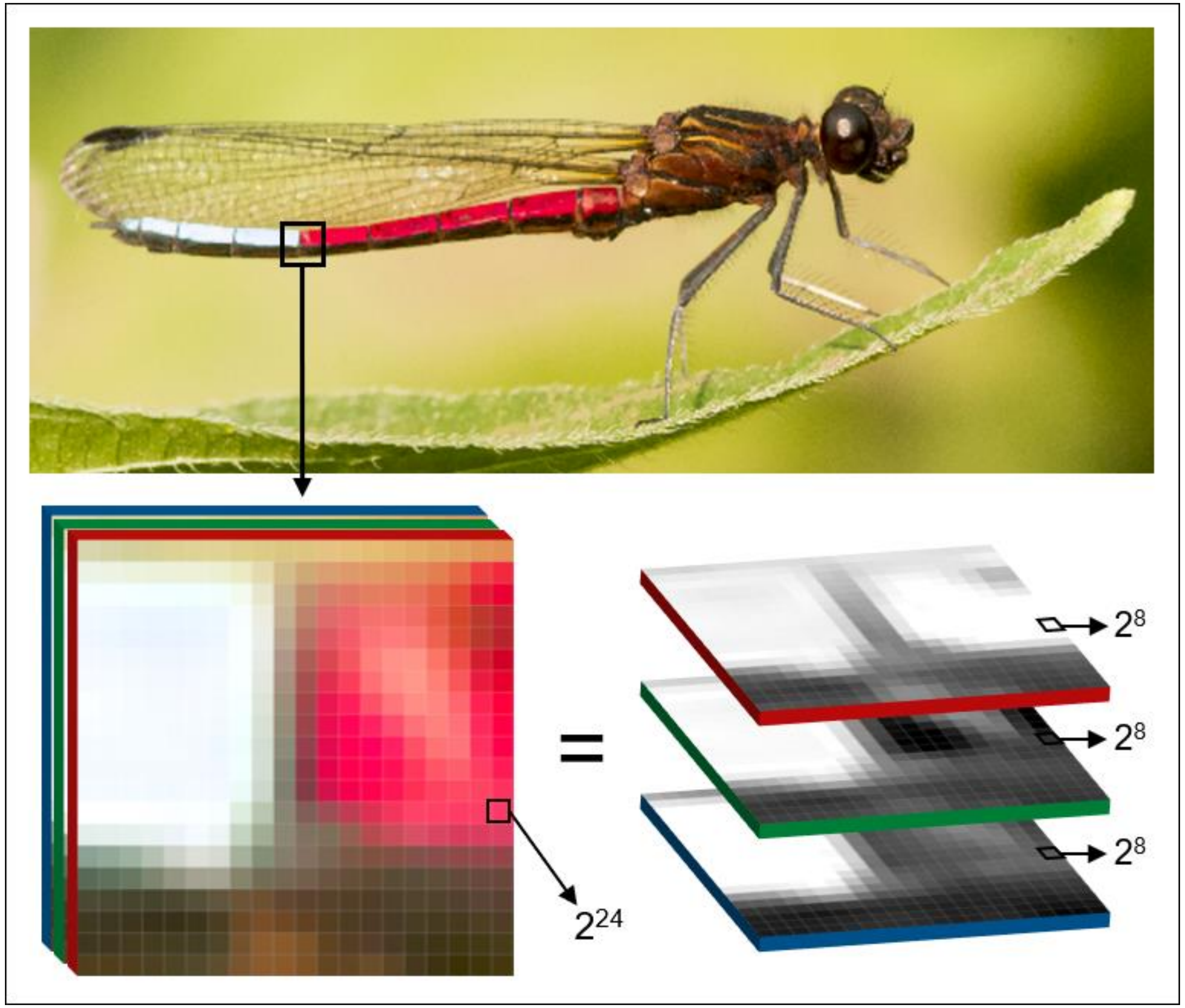
Introduction: Computer vision

Digital images



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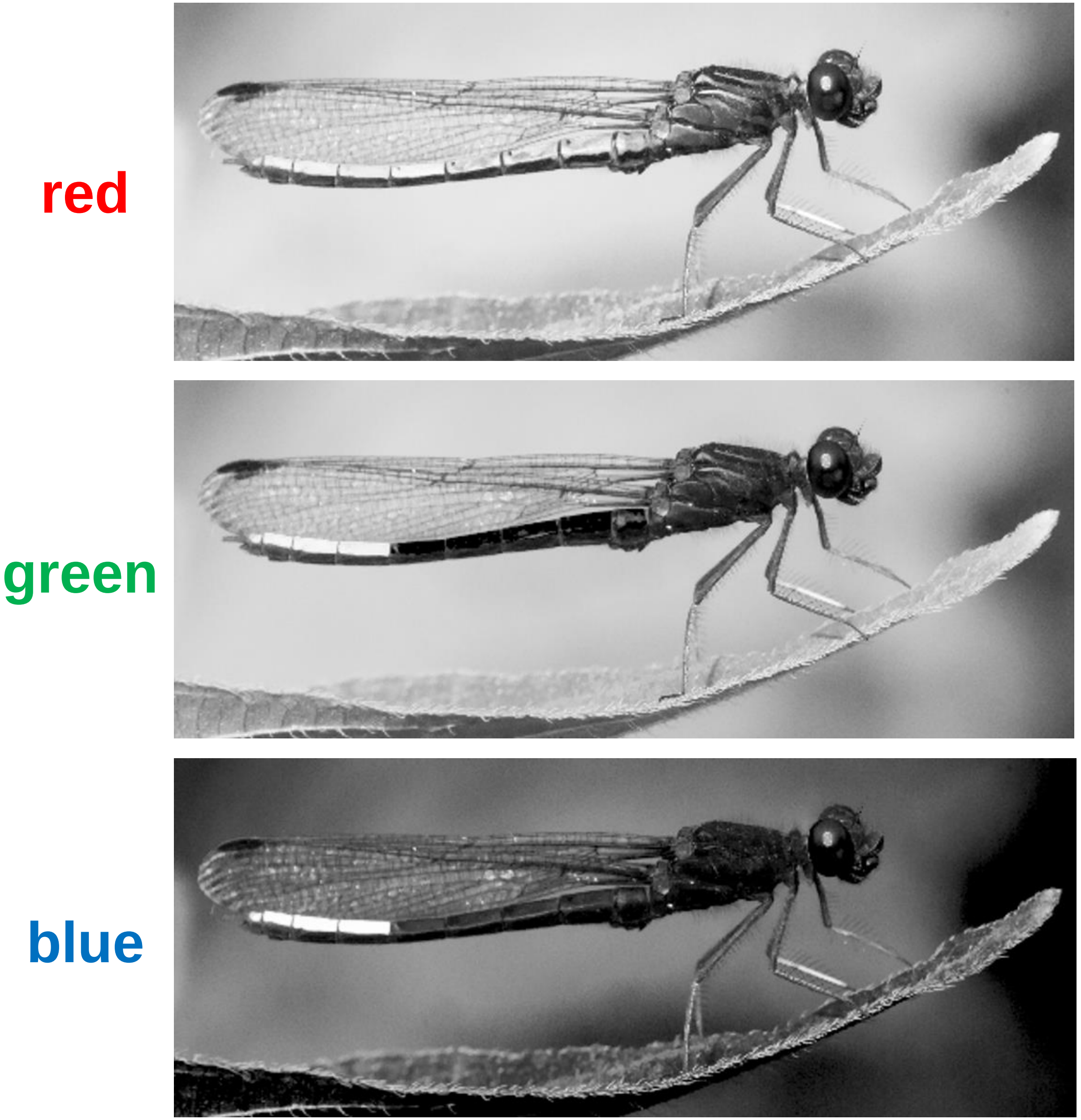


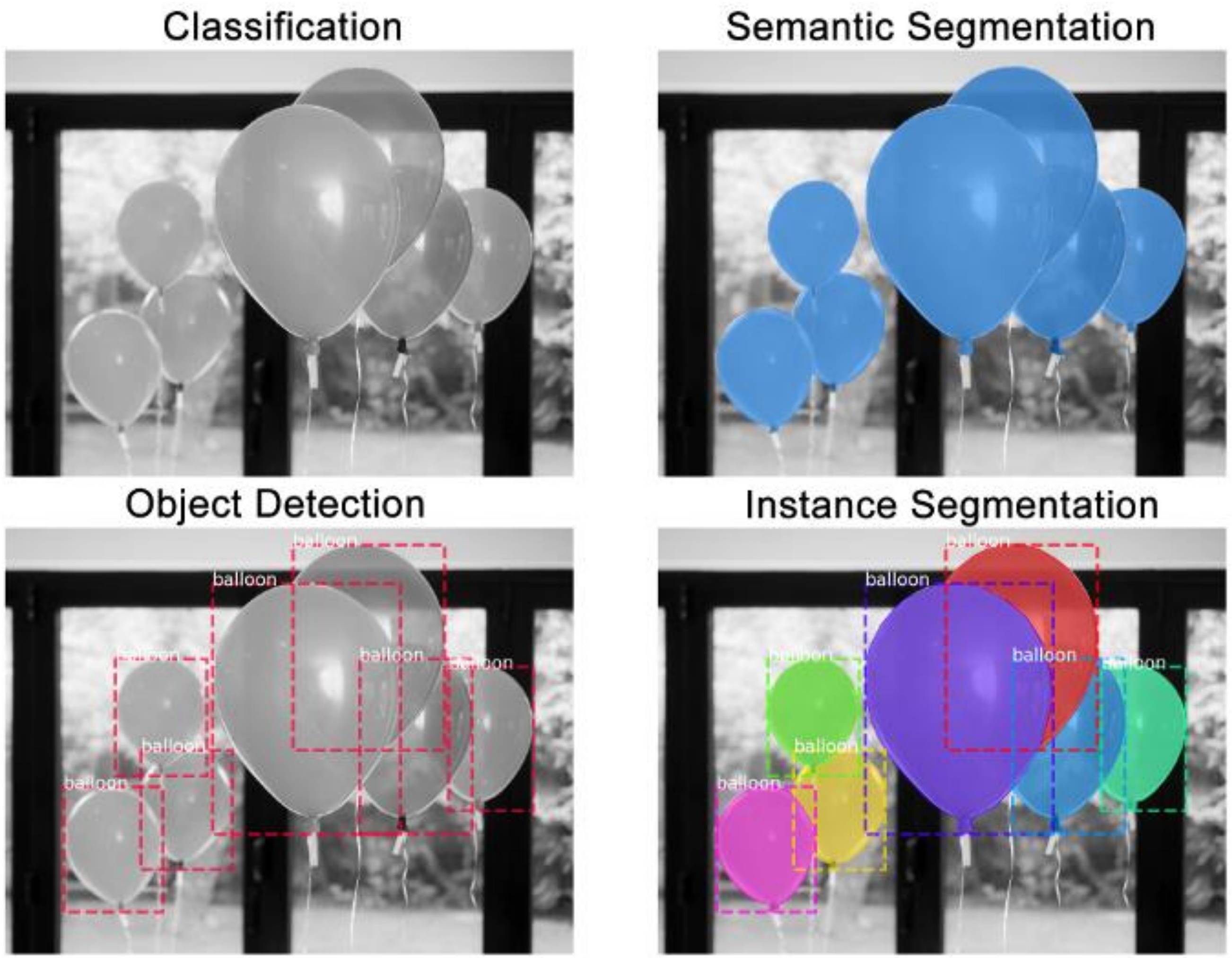
Computer vision

CV tasks

- Classification
- Object detection
- Segmentation (semantic + instance)

(Not shown)

- Key points / pose estimation
- Object tracking

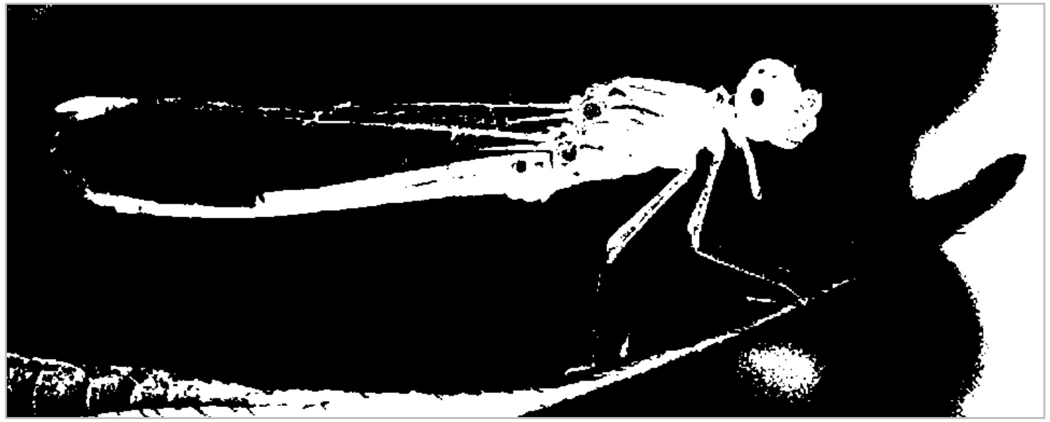


Signal-processing-based segmentation

Grayscale

Signal-processing-based segmentation

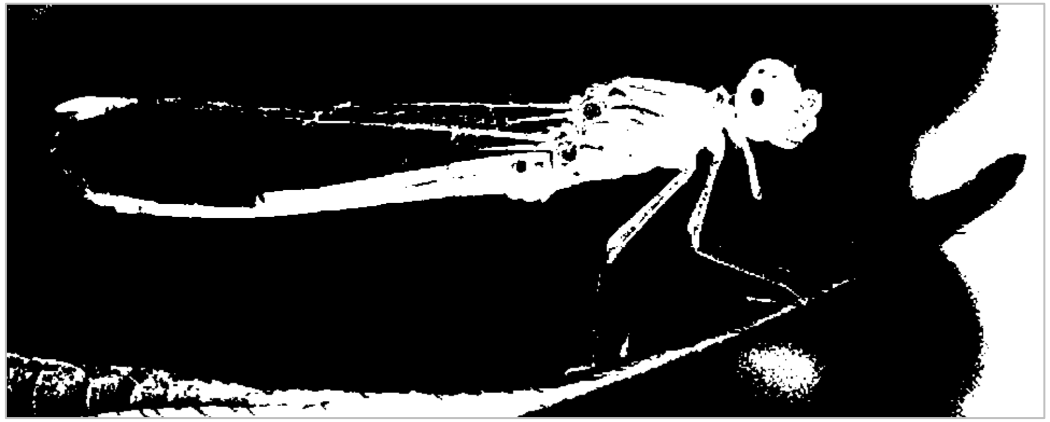
Grayscale



Binary threshold (val=127)

Signal-processing-based segmentation

Grayscale



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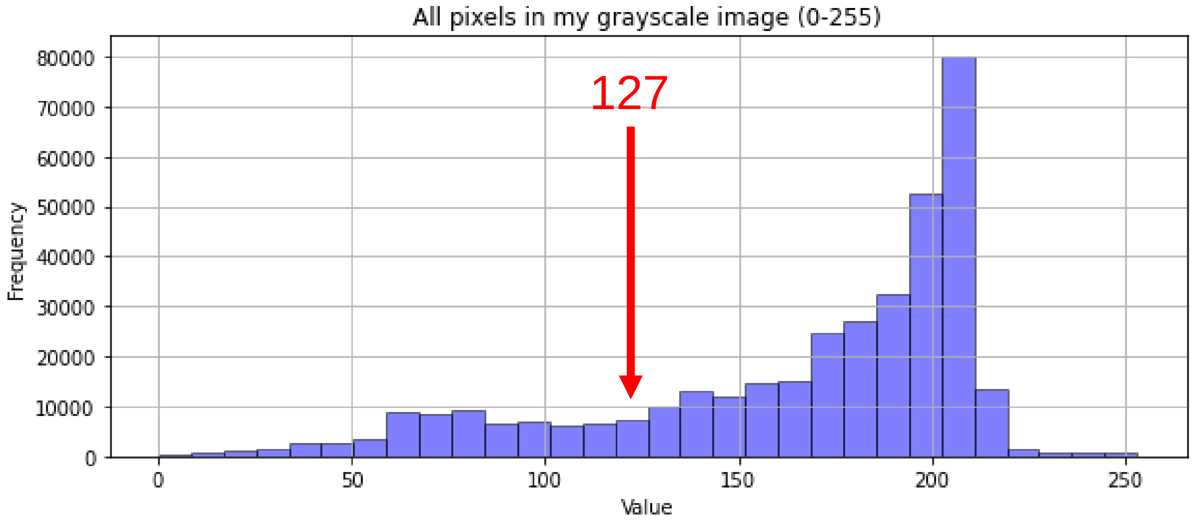

Introduction: Computer vision

Signal-processing-based segmentation

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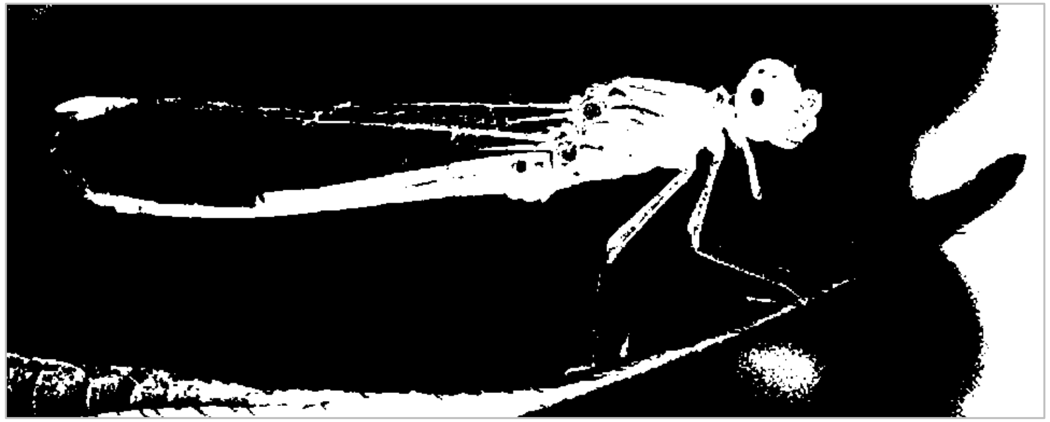

Binary threshold (val=127)

Gaussian blur + Otsu threshold

Introduction: Computer vision

Signal-processing-based segmentation

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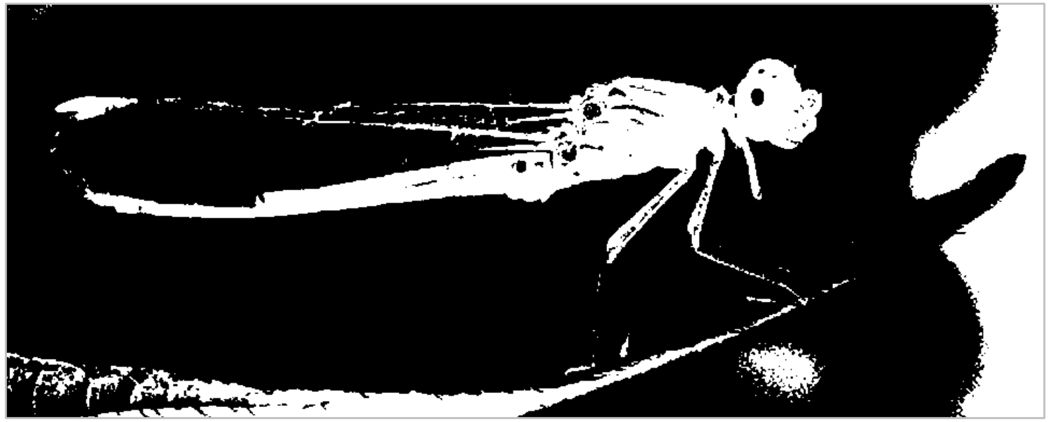


Binary threshold (val=127)

Gaussian blur + Otsu threshold

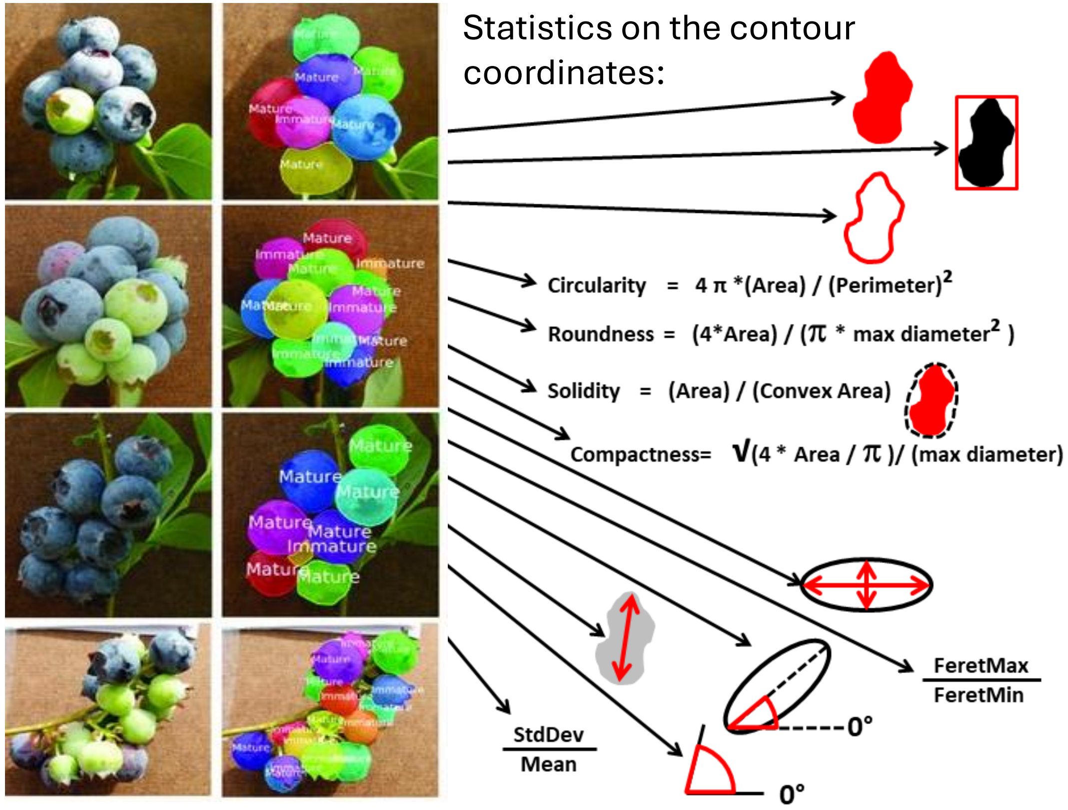
Final mask

Introduction: Computer vision

Trait extraction

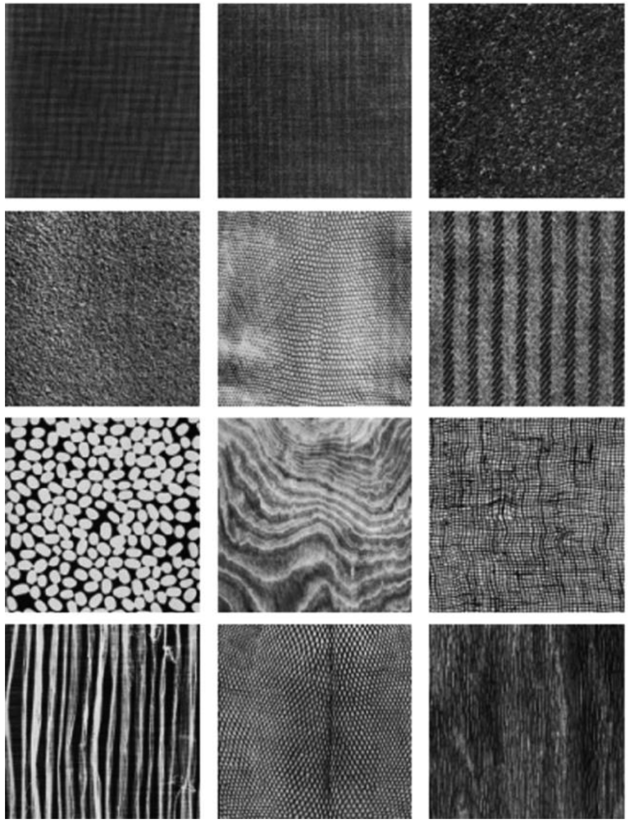
Shape features

use contour pixels of mask



Texture features

use all pixels within mask



Statistics on the spatial distribution of pixels in each channel (RGB / HSV):

- Minimum, maximum, Mean, Median
- Skewness, Kurtosis, Variance
- Uniformity, Clusteredness
- Entropy
- Gray-Level matrices
- Higher level neighborhood interactions
- …

Practical: Computer vision

< Practical part - open 01_computer_vision.ipynb>

Introduction: Clustering

Finding our way through big data

Biological datasets can be vastly diverse and complex, which requires not just examination, but also organization and understanding.

Machine learning offers a powerful approach to make sense of such complex data. Specifically, unsupervised methods such as clustering algorithms aim to identify inherent groupings in the data based on similarities among data points.

This process is somewhat analogous to the way biologists classify organisms into taxa based on shared characteristics.

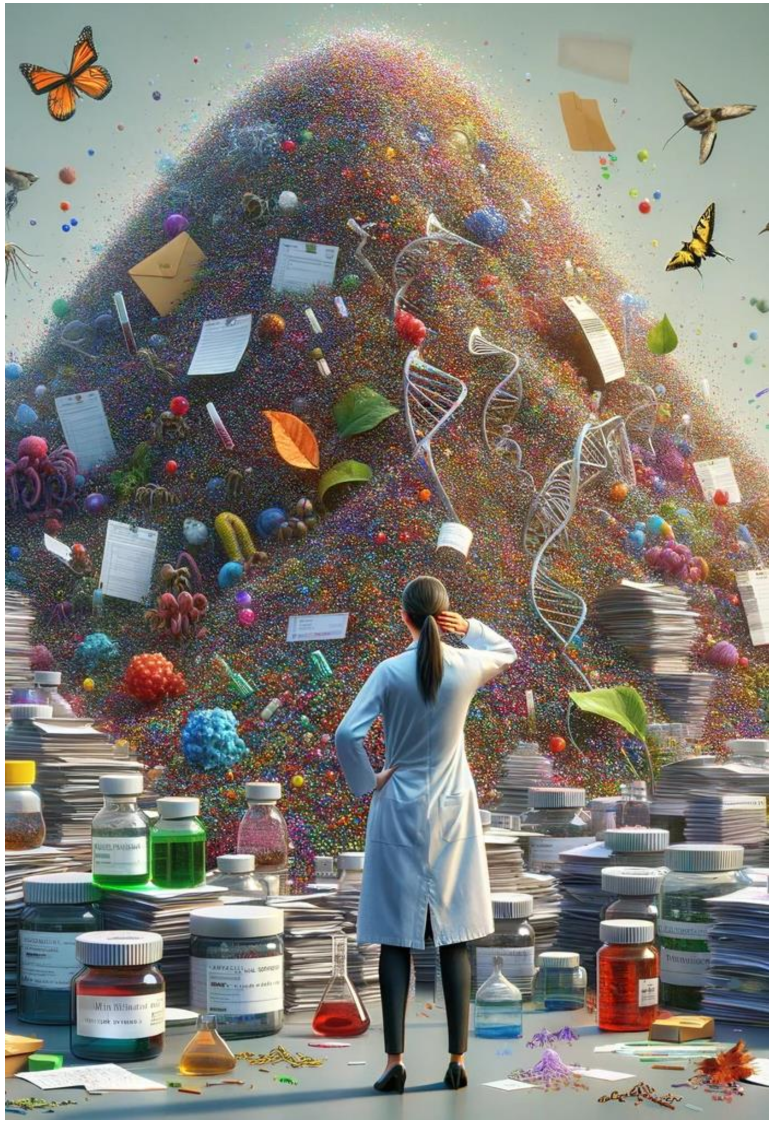


Figure: DALL-E

Unsupervised vs. supervised machine learning

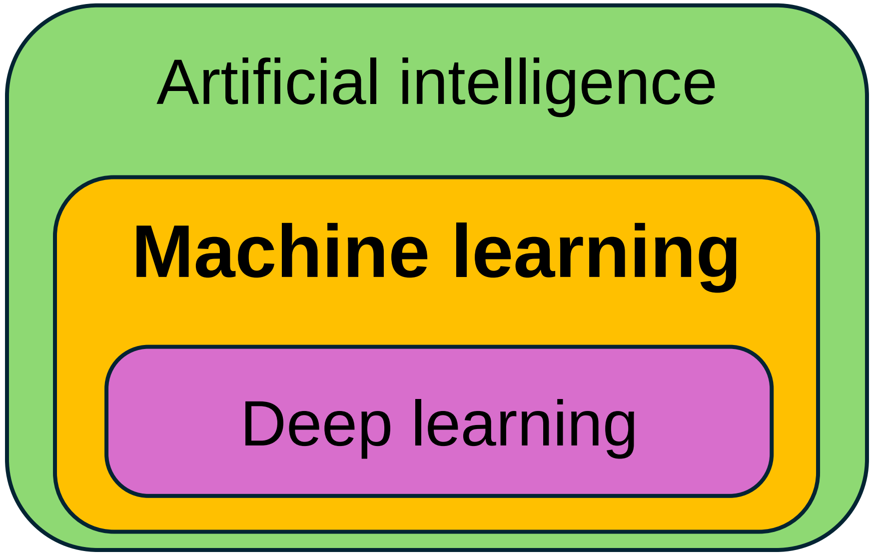
Machine learning – the study of algorithms that can learn from observational data, which involves training (on labeled/unlabeled data) and making predictions or decisions based on input data.

Subset of

Artificial intelligence (broader in scope, may combine different model-types and architectures to simulate “intelligence”

Superset of

Deep learning (artificial neural networks, often with many layers [=deep])



Introduction: Clustering

Unsupervised vs. supervised machine learning

Machine learning – the study of algorithms that can learn from observational data, which involves training (on labeled/unlabeled data) and making predictions or decisions based on input data.

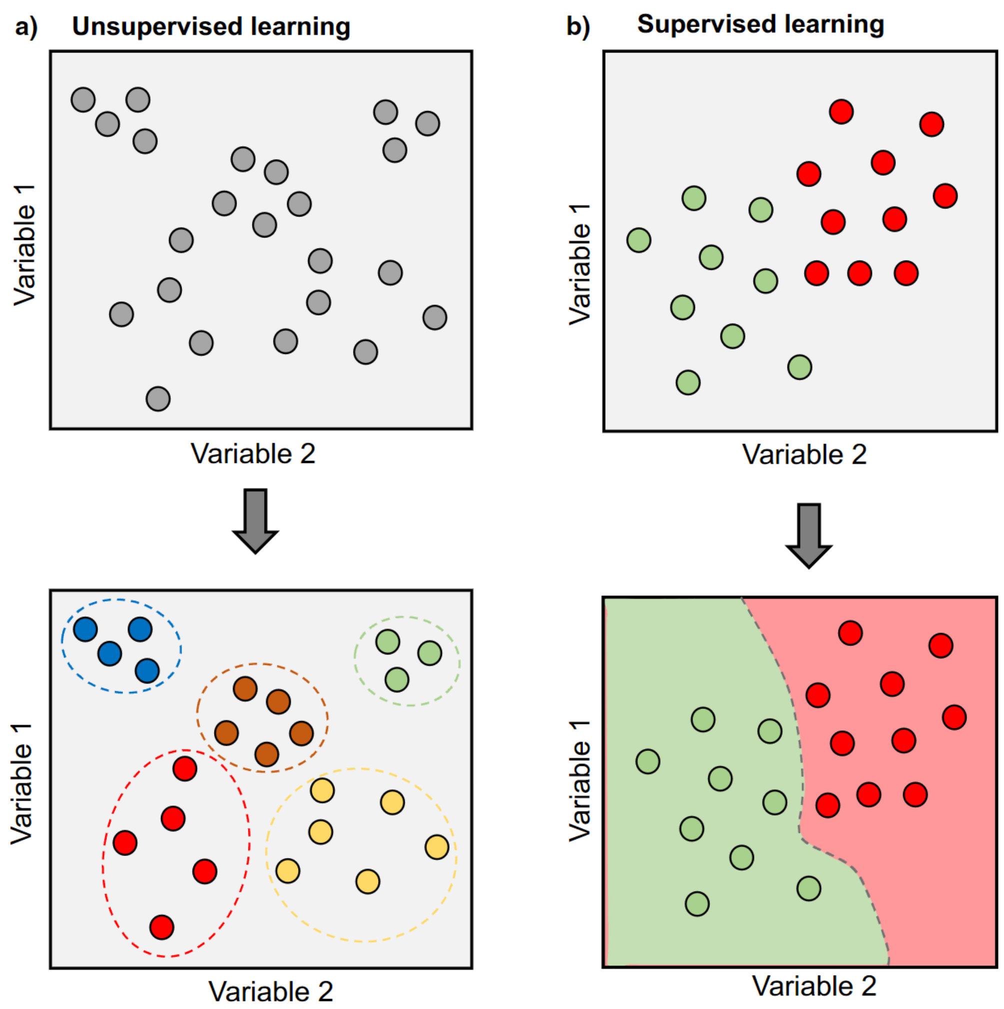
Purpose

- Prediction of a class or a value
- Pattern recognition and feature extraction

Useful when:

- Human expertise is limited or does not exist (taxonomists)
- Huge amounts of data are available (~2 billion museum specimens)
- Models need to be customized (to a taxonomic group)

Unsupervised vs. supervised machine learning

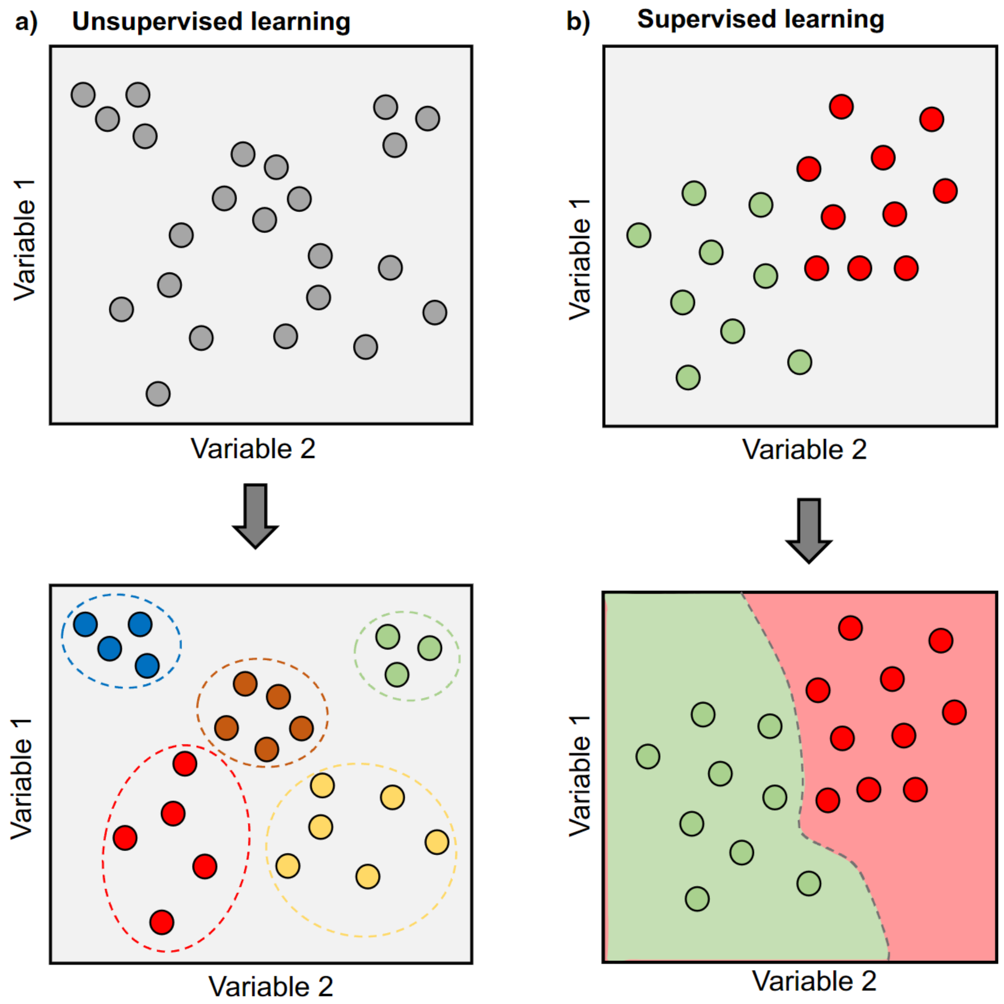


Unsupervised vs. supervised machine learning

Traits
(morphological,
functional,
chemical)

↓

Separation
into functional
groups



Introduction: Clustering

Unsupervised vs. supervised machine learning

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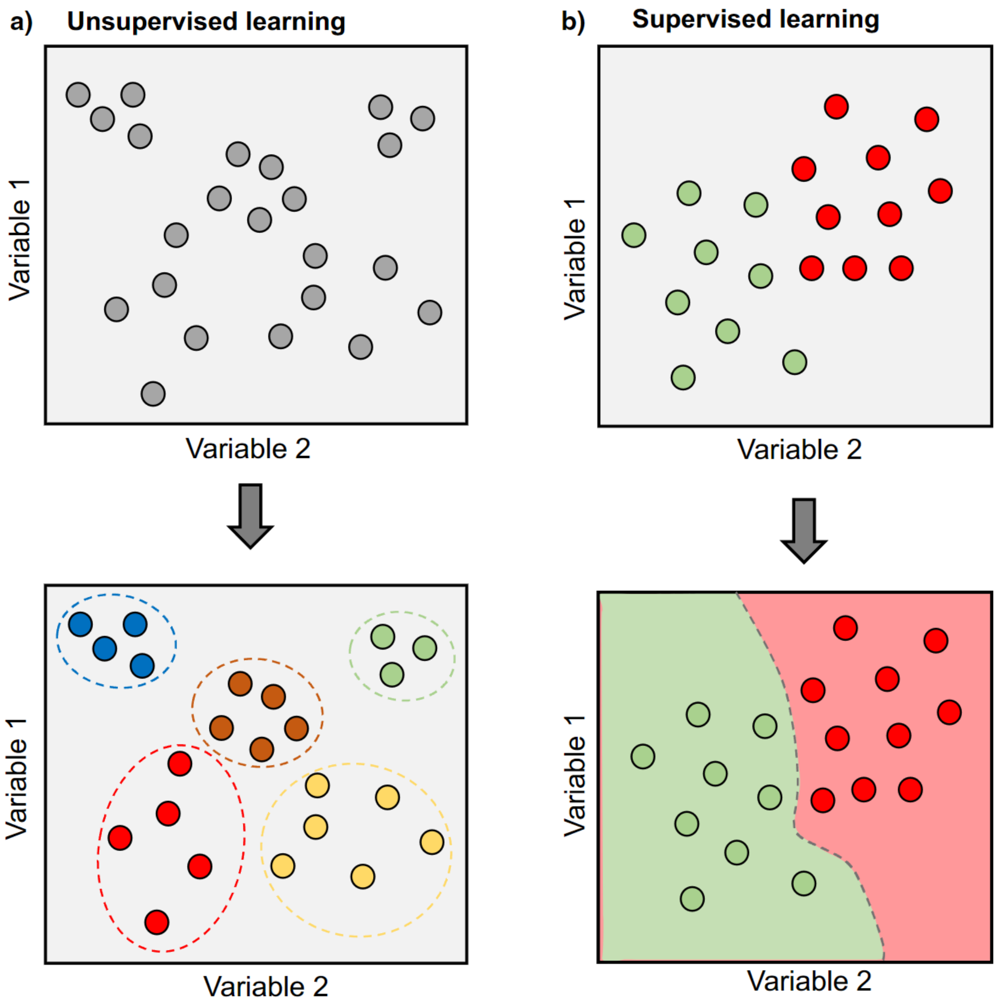
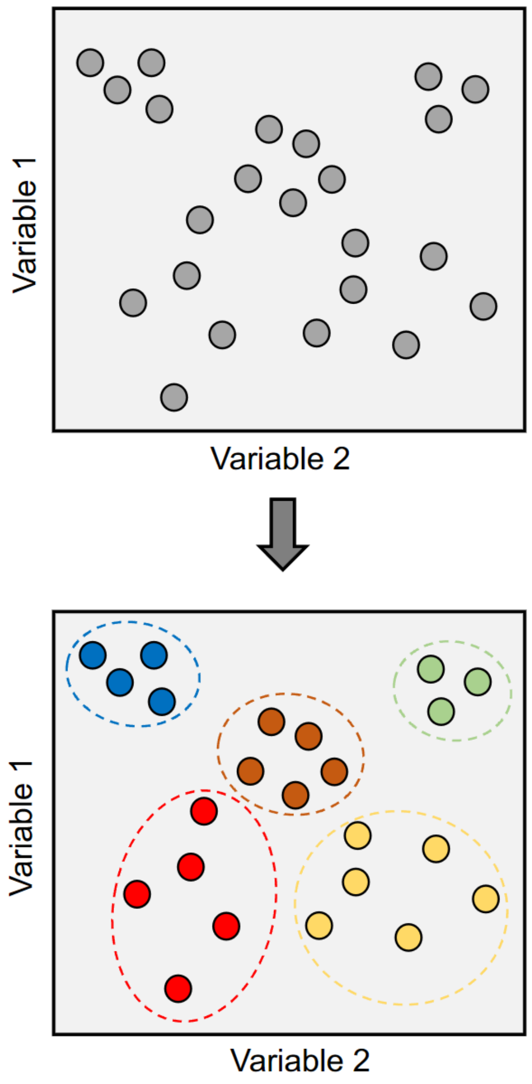


Traits + labels
(e.g., species)

Species
identification

Clustering

Definition - type of unsupervised learning that involves grouping a set of observations in a way that members of a group (the *cluster*) are more similar to each other than to those in other groups.



Purpose - discovery of inherent groupings within in datasets

Common algorithm: k-means

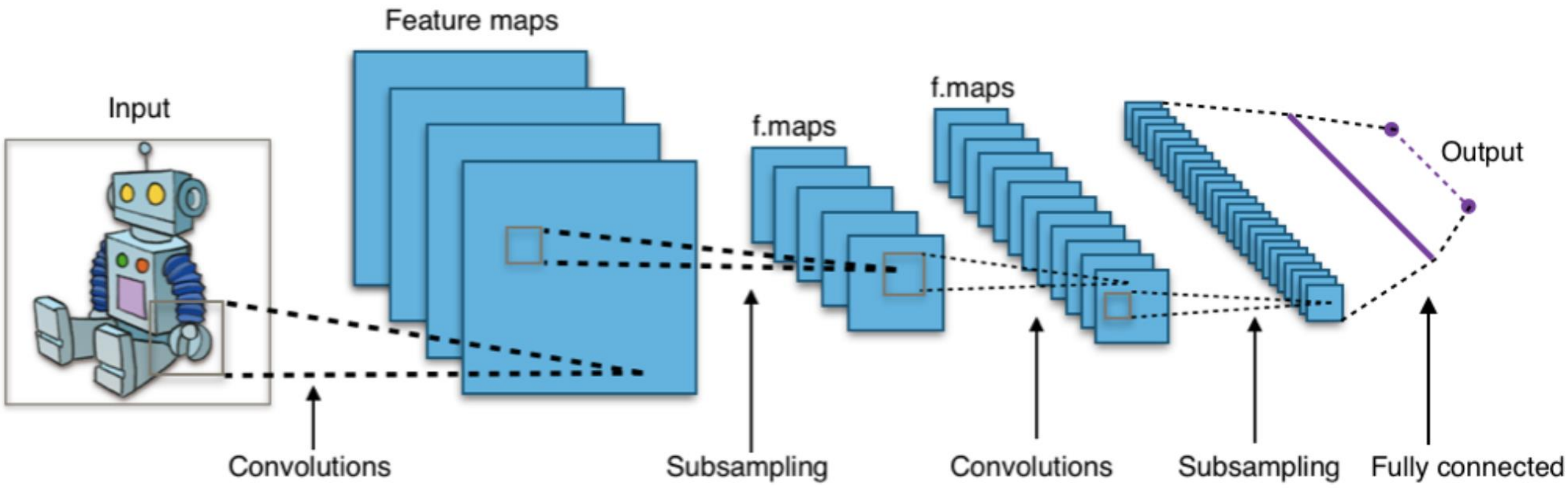
Practical: Clustering

< Practical part - open 02_clustering.ipynb>

Computer vision

Deep learning

Family of machine learning models based on neural networks – e.g., convolutional neural networks

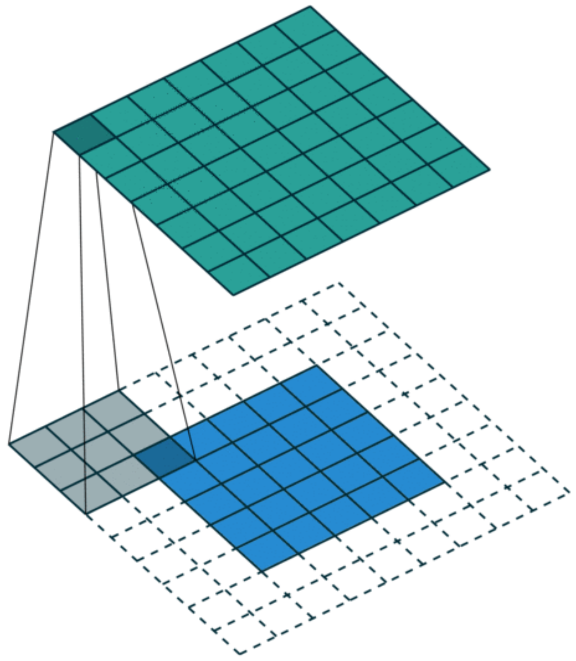


Condensation of information

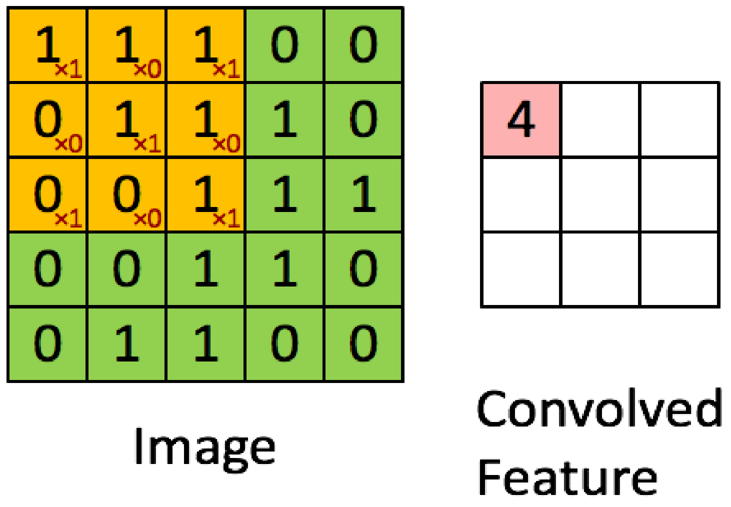
Computer vision

Deep learning

Convolutions are mathematical operations by which information contained in images is condensed through multiple layers of abstraction.



Kernel iterates over image array



Deep learning

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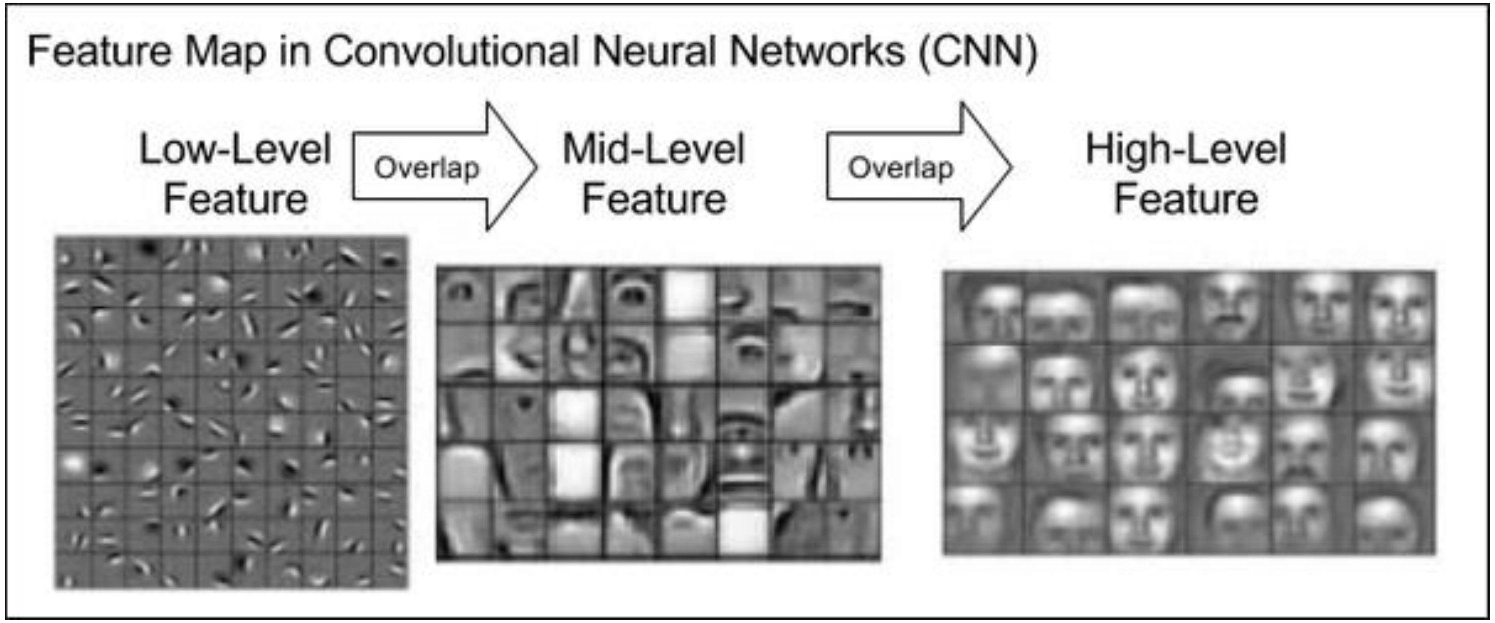

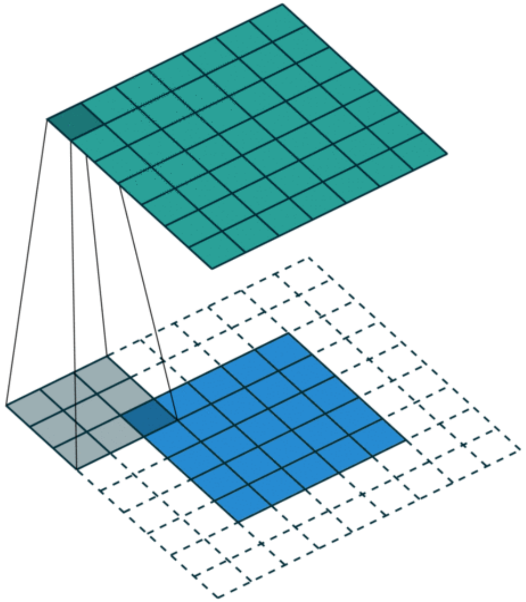

Model compares image sections with learned feature / feature space for segmentation

Deep learning

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