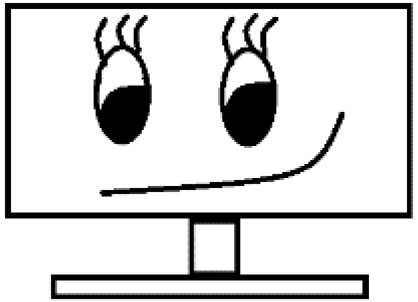
Seneca



CVI620/ DPS920 Introduction to Computer Vision

Computer Vision Problems and Methods

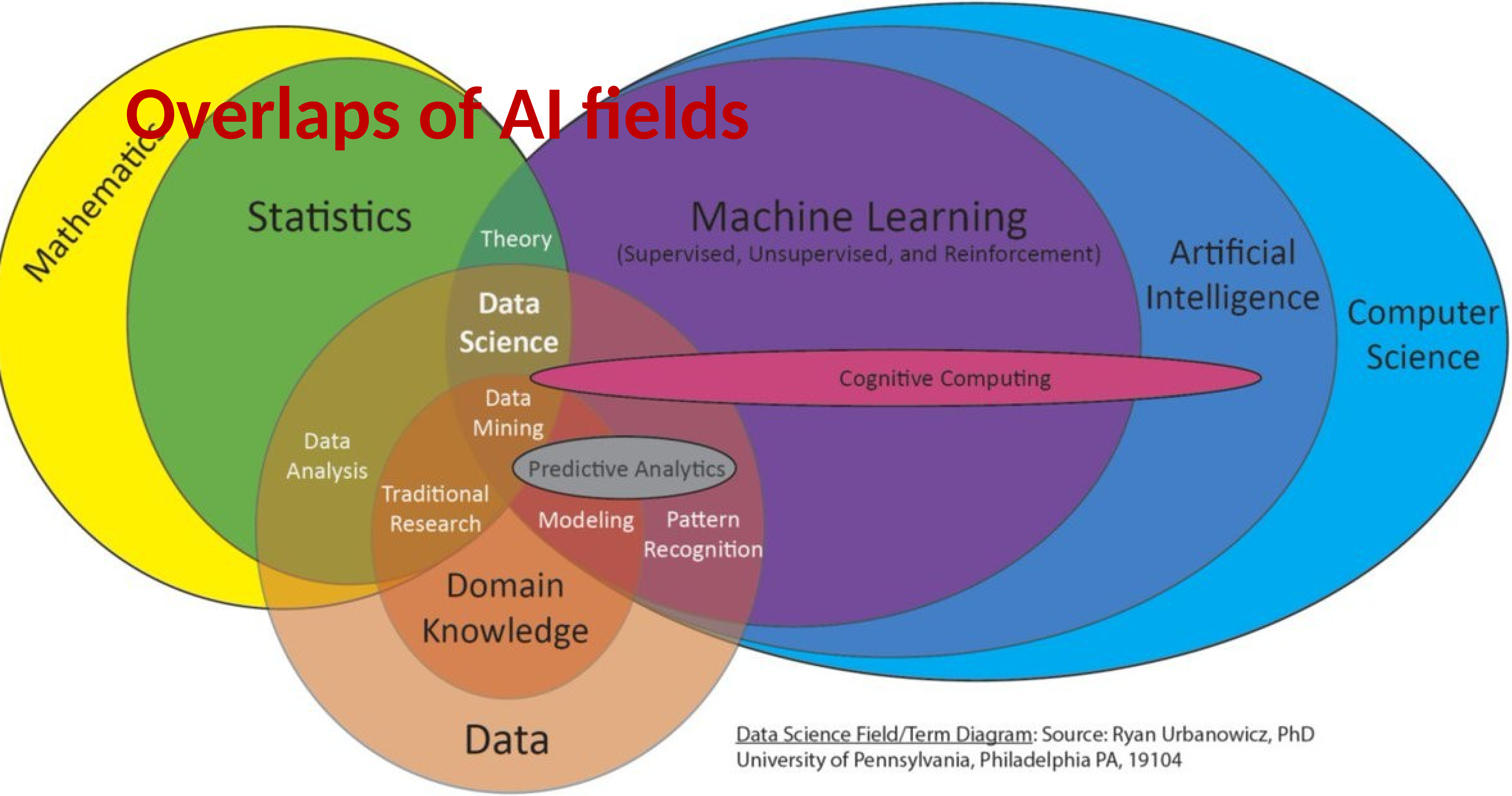
Seneca College

Overview

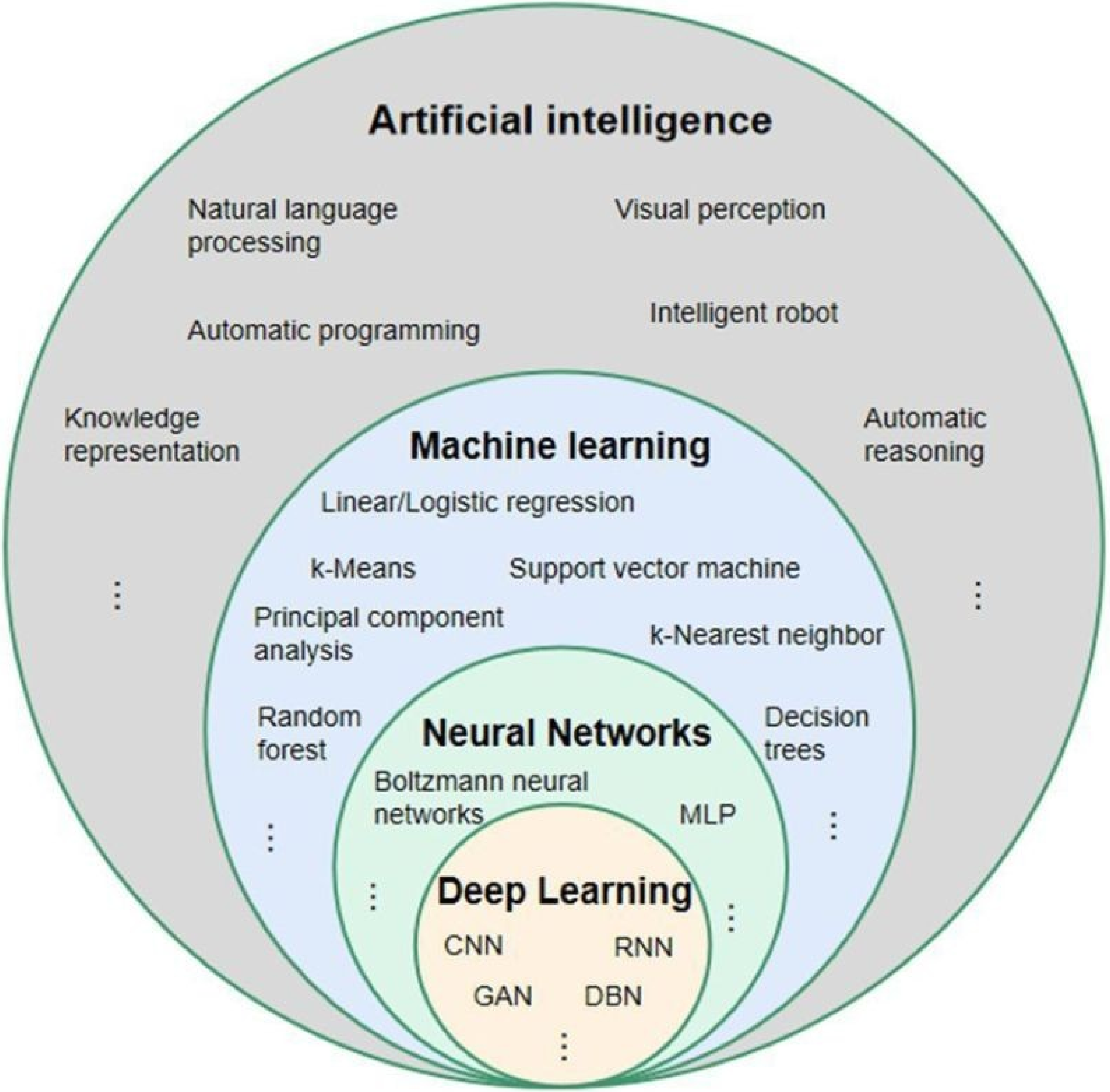
Machine Learning for Computer Vision

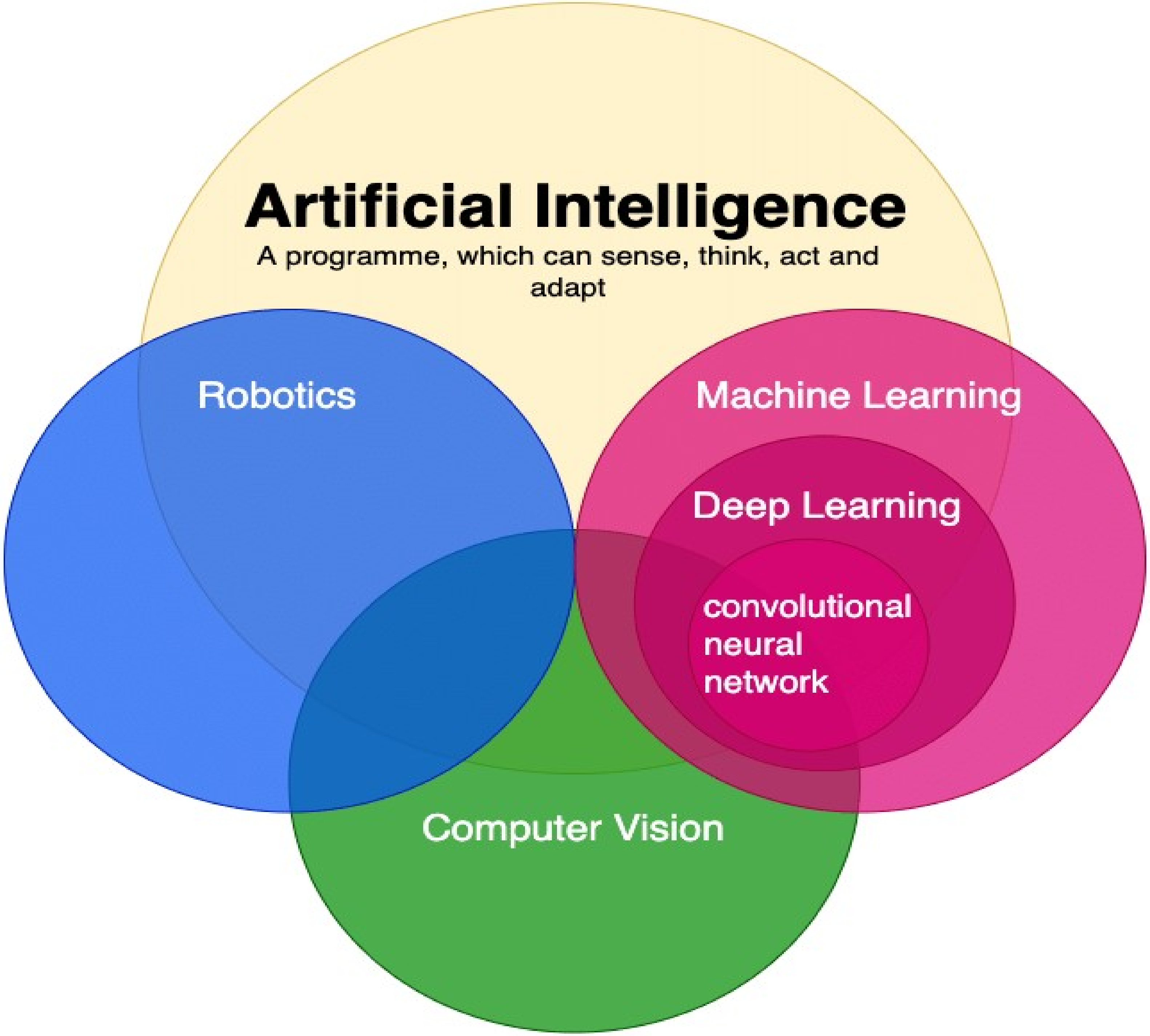
- A simple computer vision problem
- Features
- Problems and Methods
  - Classification, Clustering, Regression
  - Supervised, Unsupervised, Semi-Supervised

Overlaps of AI fields



Data Science Field/Term Diagram: Source: Ryan Urbanowicz, PhD
University of Pennsylvania, Philadelphia PA, 19104


Artificial intelligence
Natural language processing
Visual perception
Automatic programming
Intelligent robot
Knowledge representation
Automatic reasoning
⋮
⋮
Machine learning
Linear/Logistic regression
k-Means
Support vector machine
Principal component analysis
k-Nearest neighbor
Random forest
Decision trees
⋮
⋮
Neural Networks
Boltzmann neural networks
MLP
⋮
⋮
Deep Learning
CNN
RNN
GAN
DBN
⋮


Artificial Intelligence
A programme, which can sense, think, act and adapt
Robotics
Machine Learning
Deep Learning
convolutional neural network
Computer Vision

https://www.researchgate.net/figure/Relation-between-Artificial-Intelligence-Machine-Learning-and-Deep-Learning-Computer_fig1_342978934

Example: Assembly Line Inspection

- Design a vision system that can **detect the objects** on the assembly line

- How can you solve this problem?

https://binged.it/2TlZFLU

Solving a Computer Vision Problem

- **Method 1:** Start with intuition, implement it, use data to verify your intuition/ concept
  - Use color, size, shape, etc.
- **Method 2:** Start with data, then use features and build a model to learn how to solve the problem (Machine Learning methods)
  - Give labelled training samples and features to a machine learning algorithm
  - The algorithm automatically builds a model for detection
- **Method 3:** Start with LOTS of data and an intuition about the Neural Net architecture, train the NN to solve the problem

- https://www.quora.com/What-is-the-alternative-to-machine-learning

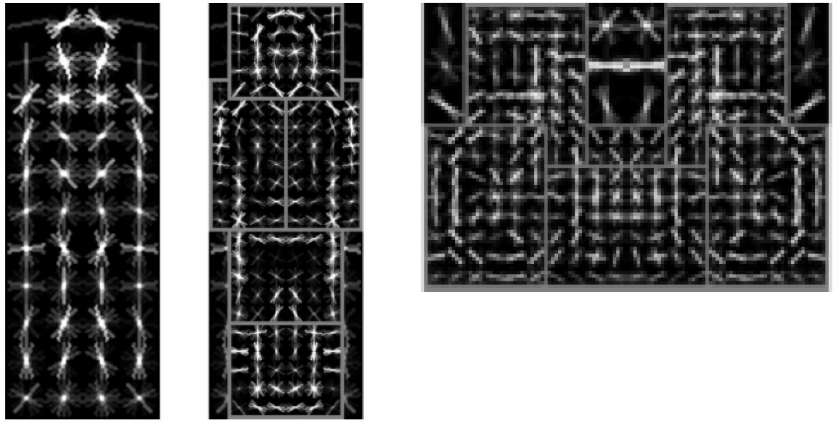
Features

- In **Machine Learning**, features are **data measurements or information** that can be used to predict a target value.
- In **computer vision**, in addition to above, specific structures in images, e.g. edges, corners, etc. are also referred to as **features**.

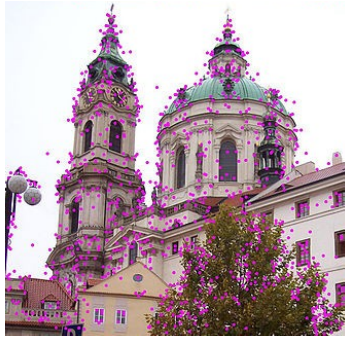
https://en.wikipedia.org/wiki/Scale-invariant_feature_transform

Features

- In **Machine Learning**, features are **data measurements or information** that can be used to predict a target value.
- In **computer vision**, in addition to above, specific structures in images, e.g. edges, corners, etc. are also referred to as **features**.
- Examples of commonly used image features:
  - Color: e.g. color histogram (bin values)
  - HoG: Histogram of Oriented Gradients
  - SIFT: Scale-Invariant Feature Transform
  - Shape Features



http://cs.brown.edu/people/pfelzens/papers/lsvm-pami.pdf



https://en.wikipedia.org/wiki/Scale-invariant_feature_transform

Method 1 (General AI)

Example: Assembly Line Inspection

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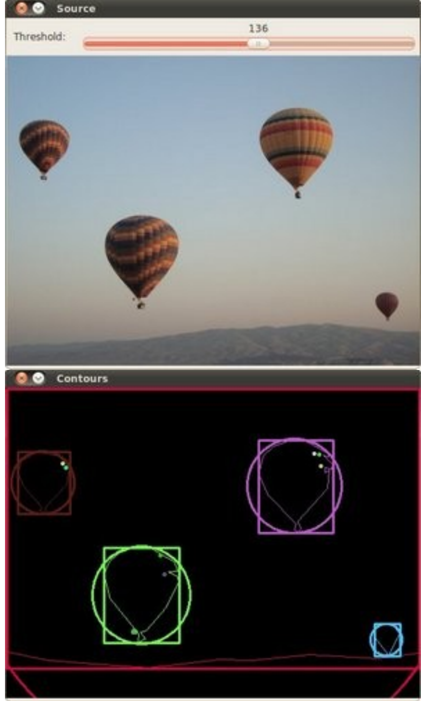
Shape Features [3]



Some features used for **shape** / **object** detection

OpenCV: Contour Features

OpenCV: Creating Bounding boxes and circles for contours

- **Contour Area:** number of pixels in the shape / contour
- **Moments and Moment Invariants:** you can extract useful data like area, centroid, etc
- **Contour Perimeter or Arc Length**
- **Bounding Boxes and Circles for Contours:** The minimum bounding box/circle for a shape is the smallest box/circle which encompasses a shape.
- **Elongatedness:** How long the shape is: can be defined as the ratio of the region area divided by the square of its thickness

$$elongatedness = \frac{area}{(2d)^2}$$

More Features

- Concavities and Holes
- Rectangularity
  - Ratio of region area to the area of the minimum bounding rectangle
- Circularity
  - Circularity =
  - e.g. a perfect circle has a circularity of 1 (maximum)
  - e.g. a regular hexagon has higher circularity than, say a square.

Similarity or Distance

- Similarity measures
  - Design a formula for finding the **similarity** between **two feature vectors**
  - For example: Correlation measures

- Distance measure
  - Or Design a formula for finding the **dissimilarity (distance)** between **two feature vectors**
  - For example: Euclidean distance

Method 2 (ML-Based)

Example: Assembly Line Inspection

- Design a vision system that can **detect the objects** on the assembly line

- How can you solve this problem?

https://binged.it/2TlZFLU

Machine Learning - Definition

- “Machine learning is a branch of artificial intelligence (AI) and computer science which focuses on the use of **data and algorithms** to **imitate** the way that humans learn, gradually improving its accuracy.”- [What is Machine Learning? | IBM]

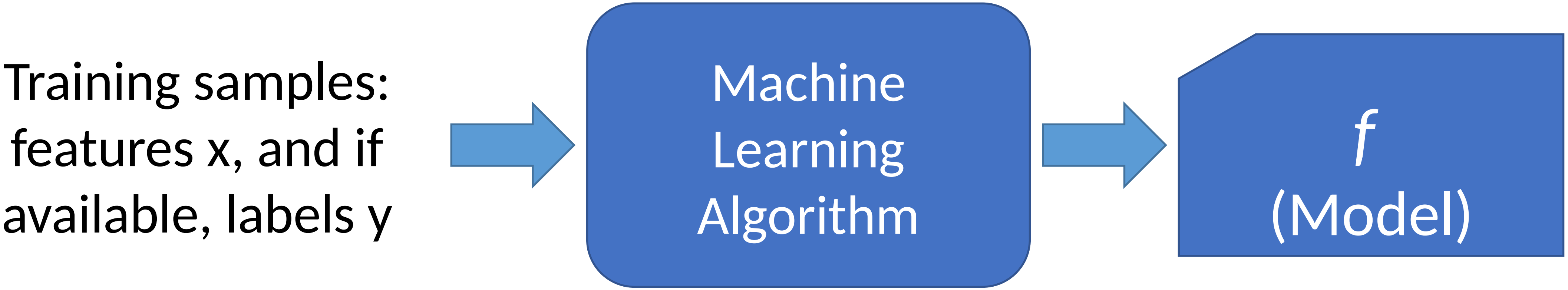
- “Solutions capable of **learning** directly from data without any predigestion to render it as symbols” – Mueller & Massaron

- “To **adapt** to new circumstances and to detect and extrapolate patterns” – Russel & Norvig

Terminology

- **x:** input, **features**, independent variables, predictors
- **y:** output, **label**, **target**, dependent variable
- **f:** function, **model**

Training or Learning a Model

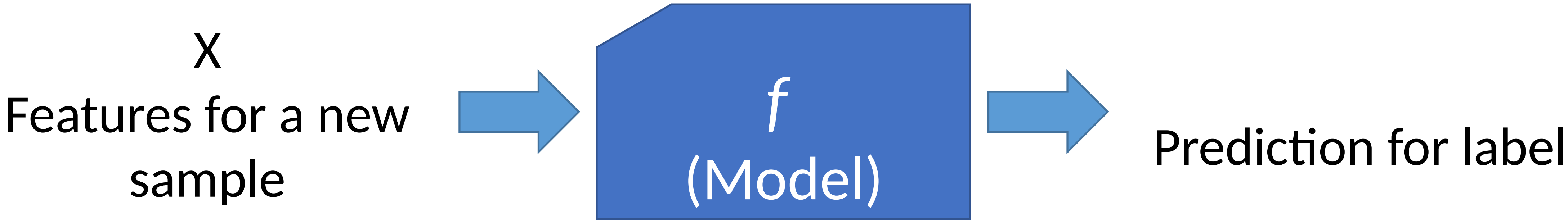


Training samples: features x, and if available, labels y

Machine Learning Algorithm

f (Model)

Use the Trained Model for Prediction



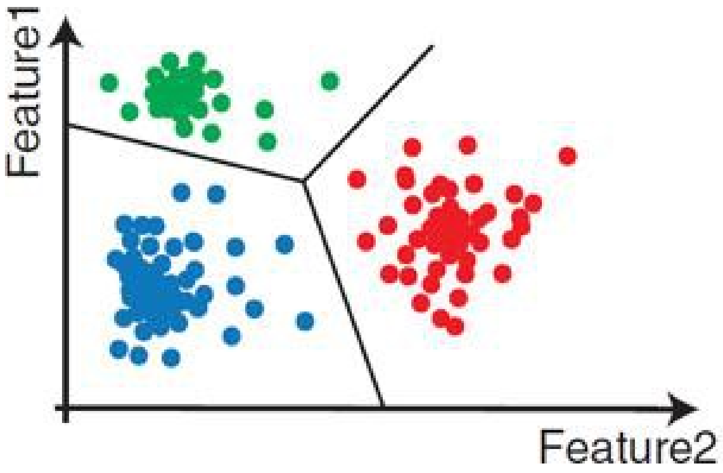
X
Features for a new sample

f
(Model)

Prediction for label

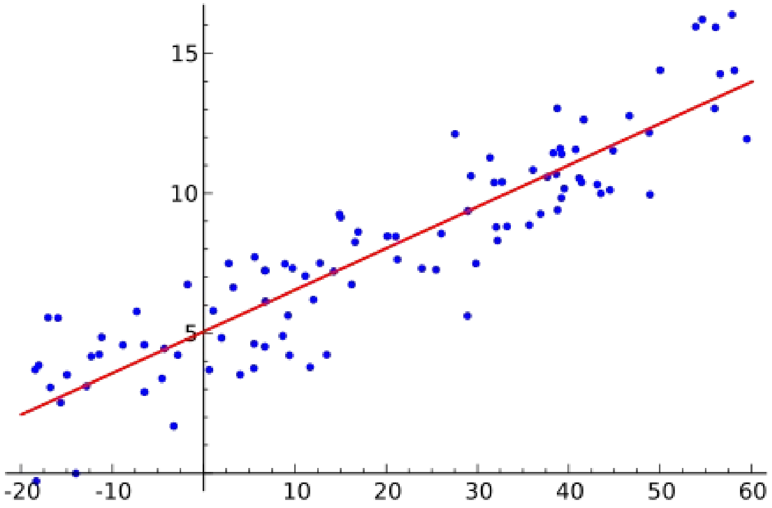
Types of Problems

Classification



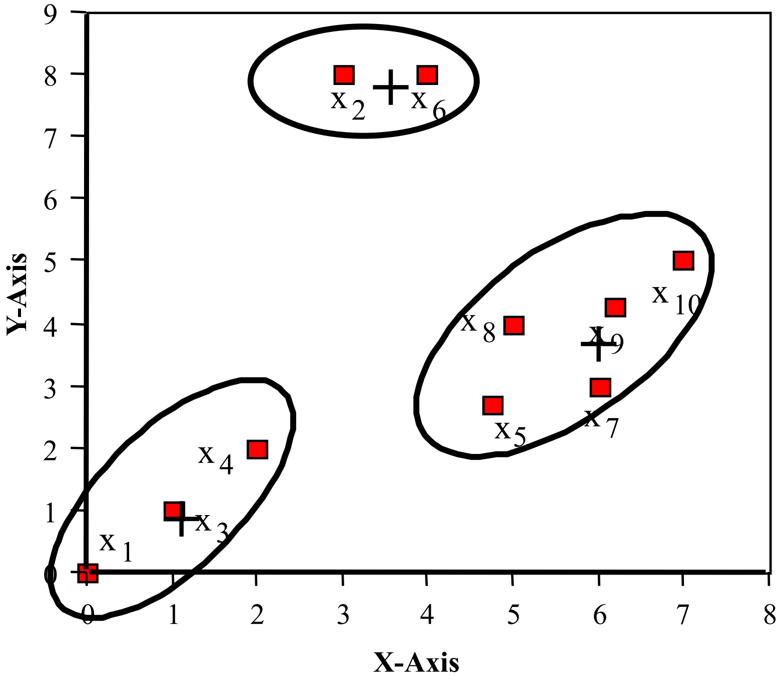
[3] Practical introduction to Computer Vision with OpenCV

Regression



https://en.wikipedia.org/wiki/Regression_analysis

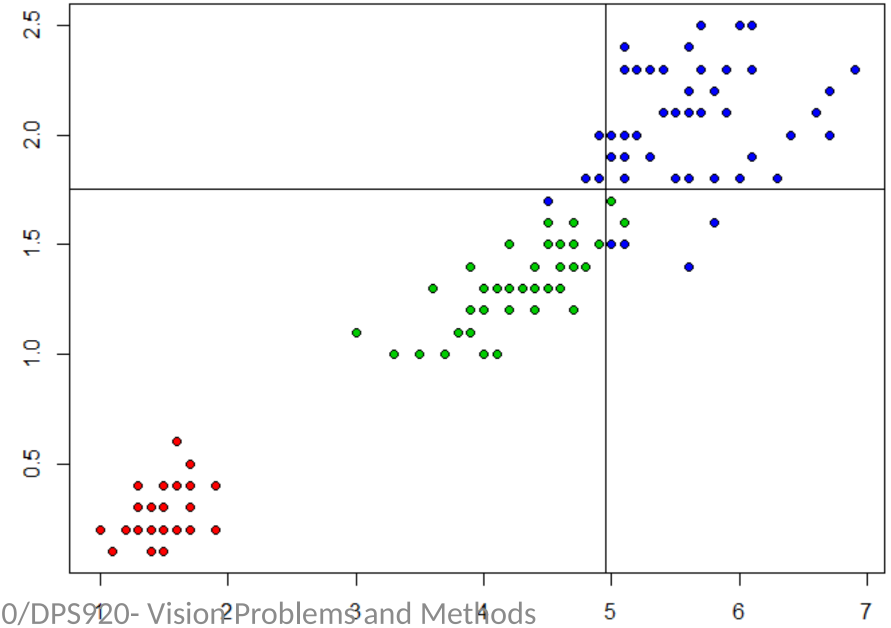
Clustering

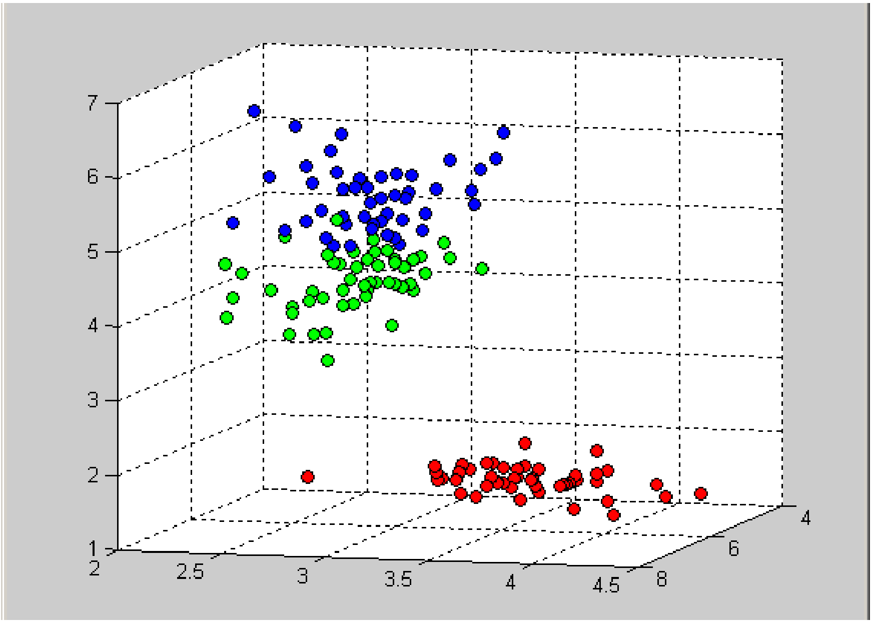


D. Abbott, Applied Predictive Analytics, Wiley, 2014

Types of Problems: (1) Classification

- Predicting a discrete target value from one or more inputs
  - Predict whether a patient is **diabetic or not**, based on glucose level, weight, age
  - Predict the type of Iris flower given measurements on petals
  - Predict whether this is an image of a car or a bus





Separable classes [3]

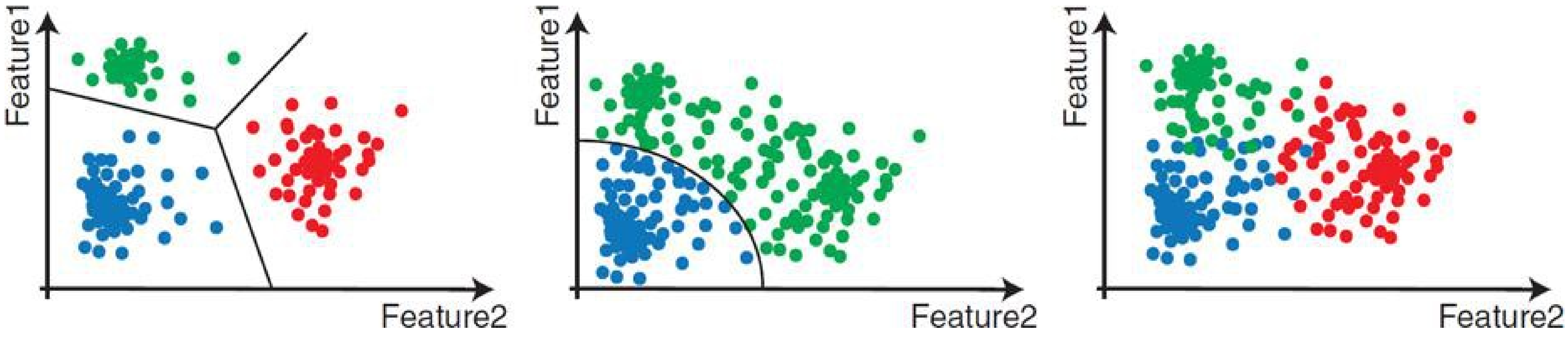
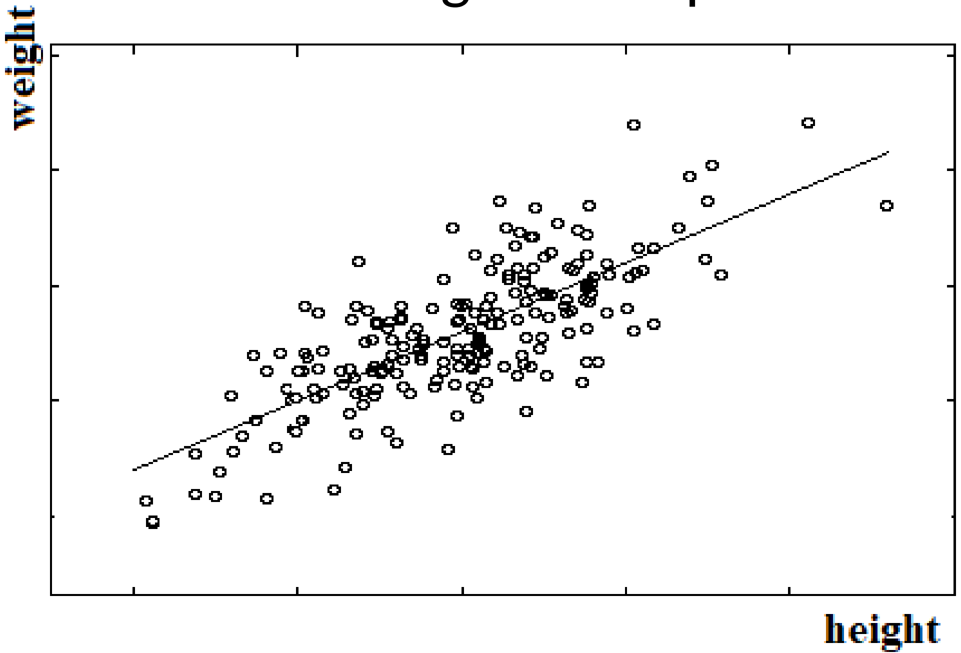
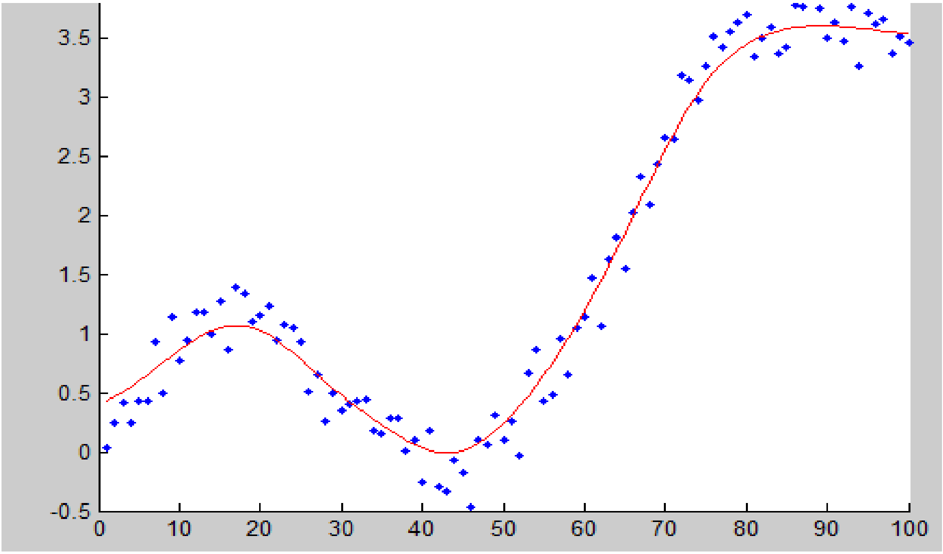


Figure 8.15: Objects of different classes (shown by dots of different colours) mapped into 2D feature space. On the left, the classes are linearly separable, in the centre, the classes are separable and a hyper-surface (a curve in this case) is shown between them, and on the right the classes are inseparable (using these features)

Types of Problems: (2) Regression

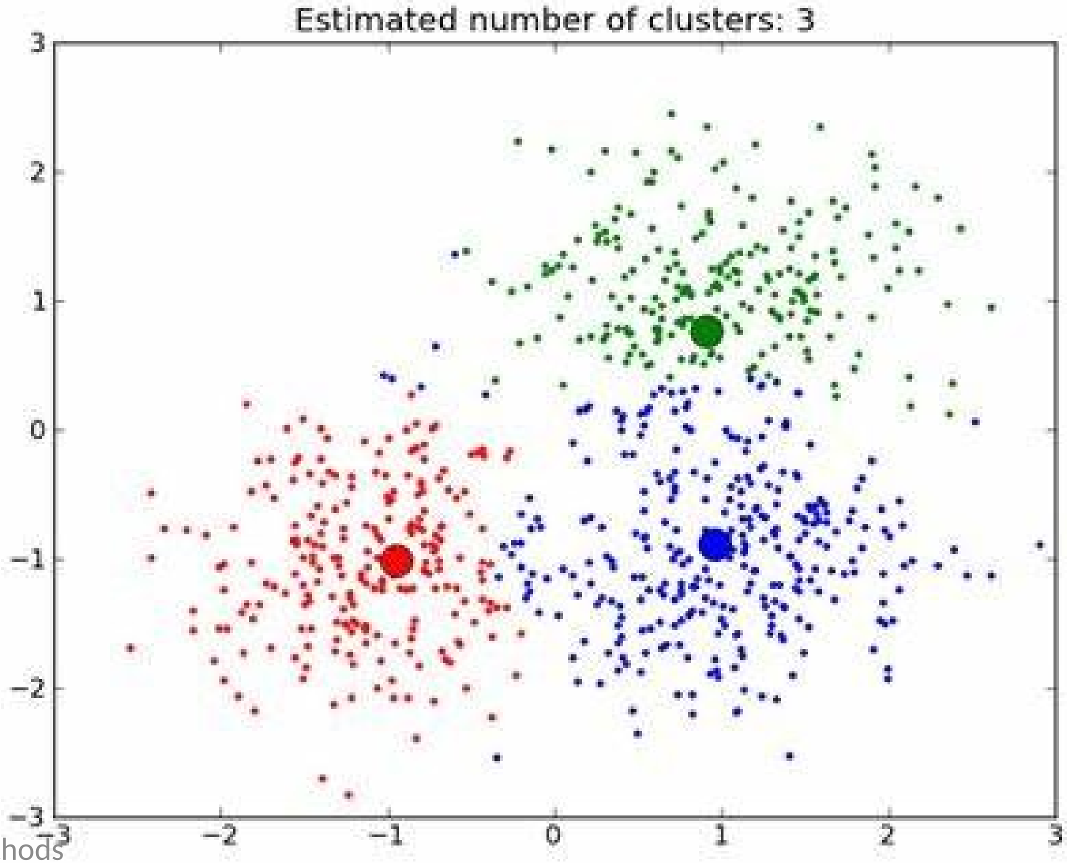
- Predicting a <u>continuous</u> target value from one or more inputs
  - Predict weight given height
  - Predict the price of a used car given age, model, color, and mileage
  - Predict the age of the person in the image





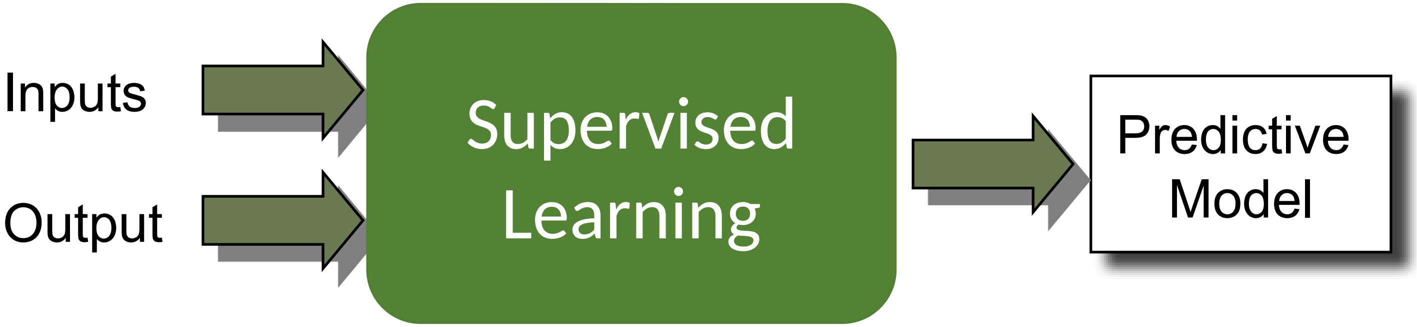
Types of Problems: (3) Clustering

- Predicting groups or clusters in data (no specific target)
- Looks like there are 3 types of rock samples gathered on Mars



Types of Models

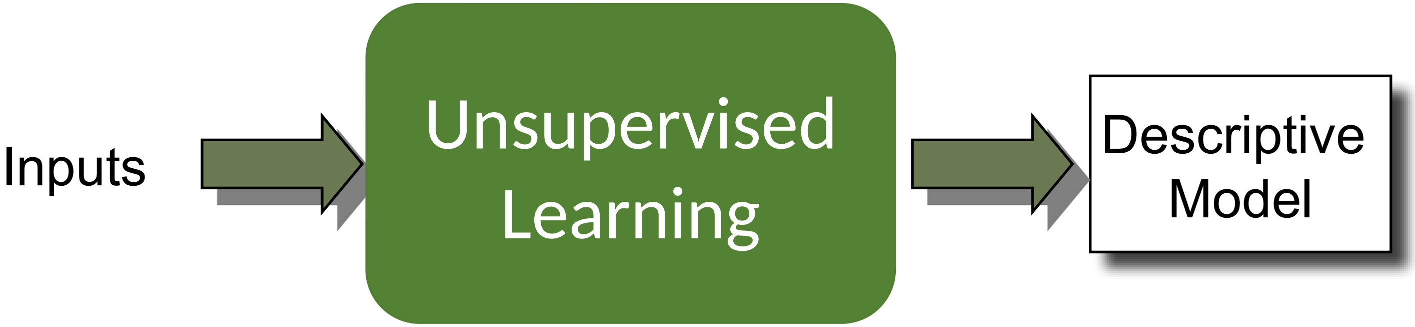
- **Supervised Learning ☾ Predictive Models**



Regression

Classification

- **Unsupervised Learning ☾ Descriptive Models**



Clustering

Supervised Learning (or Training)

- In supervised learning, training data contains for each sample:
  - **Feature vector** of the sample
  - Given **class or target value** of the sample
- The classifier or predictor is **trained** based on the samples to learn the class or target value of each sample (training data)
- But also be able to generalize & predict the class (or target value) of samples not seen (test data)

Unsupervised & Semi-Supervised Learning

- Unsupervised Training
  - Training data consists of only the feature vectors. The class, target, or cluster for each sample is unknown.
  - Learn to cluster data

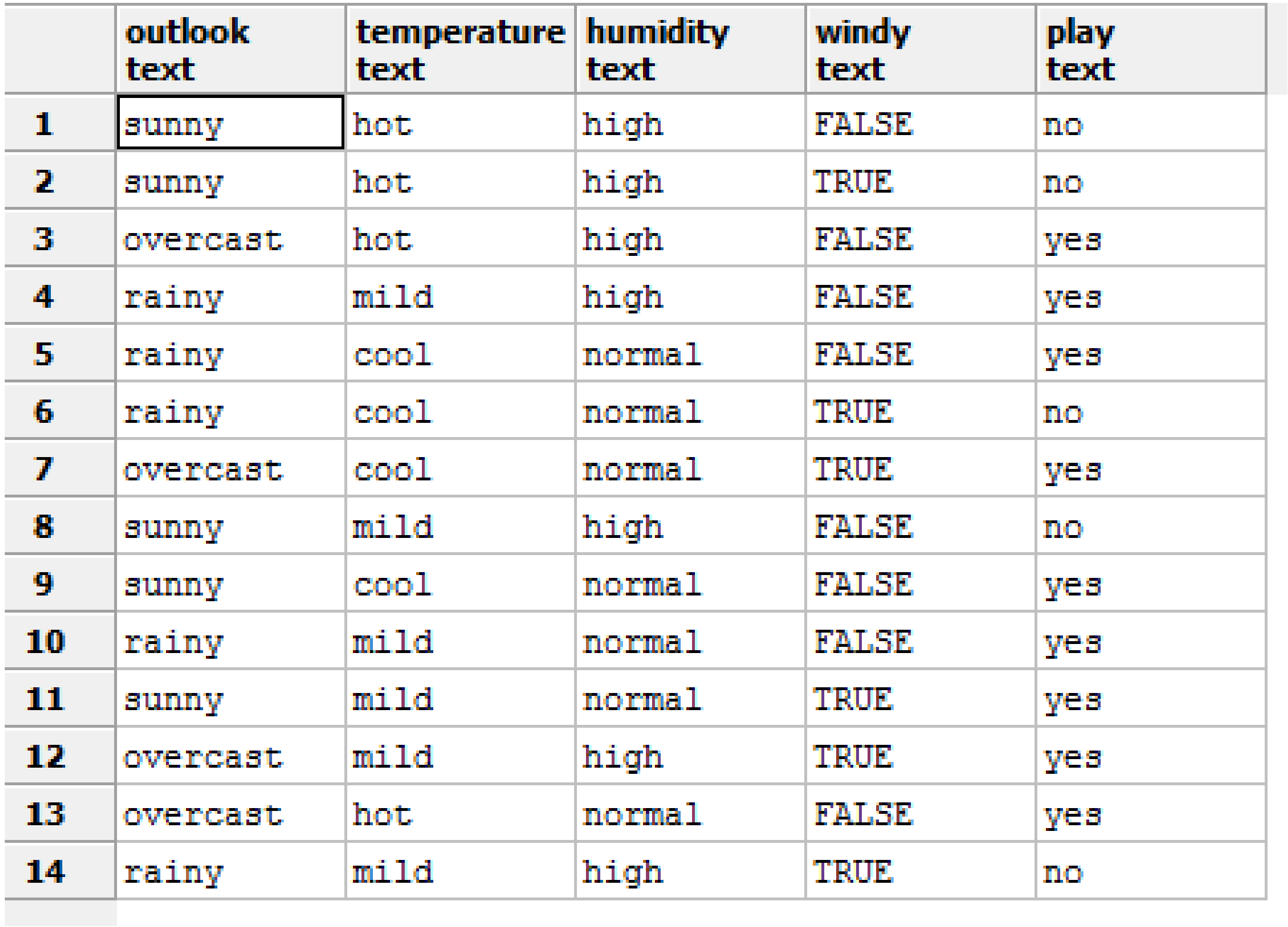
- Semi-supervised Training
  - Unsupervised, but given some feedback

Some Well-Known Methods

- Some Classifiers
  - K-nearest neighbor
    - Get votes from the closest neighbors in the feature space among training data
  - Logistic Regression
  - Decision Trees
  - Support Vector Machines (SVM)
  - Naïve Bayes
- Regression
  - Linear
  - Nonlinear
- Clustering
  - K-means

Data for ML

- Tabular data
- Clean, no missing data
- Numerical



	outlook text	temperature text	humidity text	windy text	play text
1	sunny	hot	high	FALSE	no
2	sunny	hot	high	TRUE	no
3	overcast	hot	high	FALSE	yes
4	rainy	mild	high	FALSE	yes
5	rainy	cool	normal	FALSE	yes
6	rainy	cool	normal	TRUE	no
7	overcast	cool	normal	TRUE	yes
8	sunny	mild	high	FALSE	no
9	sunny	cool	normal	FALSE	yes
10	rainy	mild	normal	FALSE	yes
11	sunny	mild	normal	TRUE	yes
12	overcast	mild	high	TRUE	yes
13	overcast	hot	normal	FALSE	yes
14	rainy	mild	high	TRUE	no

http://i.stack.imgur.com/XkdDl.png

Examples

➢Driver drowsiness

- Initial dataset: A set of images with drowsy and non-drowsy drivers
- Target: drowsy or non-drowsy (or 1 / 0)
- Features: Shape features of eyes, how closed, etc.
- Type: Classification

➢Driver drowsiness

- Initial dataset: A set of videos with drowsy and non-drowsy drivers
- Target: time in each video when the driver gets drowsy (if not at all, a negative number is returned)
- Features: Shapes of eyes in every frame, the longest time the eye stayed closed, etc.
- Type: Regression

Examples

➢Traffic Sign Detection

- Initial dataset: A set of images with traffic signs or no signs
- Target: A label for each image indicating the sign in image (0: no sign, 1: stop sign, 2: Yield sign)
- Features: ORB, SIFT, HoG, for patches in the image
- Type: Classification

➢Motion tracking

- Initial dataset: A set of videos with human motion or non-human or no motion
- Target: human motion in video or not (1 / 0)
- Features: motion features (e.g. optical flow)
- Type: Classification

Examples- cont.

➢Cash counter

- Initial dataset: A set of images of coins and paper bills
- Target: total amount of money in the image
- Features: size of circles, color, OCR (hard since not rectified), similarity with a set of templates, etc.
- Type: Regression problem

➢Driver's license detector

- Initial dataset: A set of images of driver's licenses at different angles and poses
- Target: Location of card's bounding box (x, y, w, h) – to rectify the image for OCR
- Features: specs of Hough lines, color, etc.
- Type: Regression?

Examples- cont.

- Hockey player detection
    - A set of images of hockey rinks with players
    - Target: Is this patch in image a hockey player or background
    - Features: color, HoG, shape features, etc.
    - Type: classification

Summary

- Computer Vision problems can be solved using three approaches:
  1) Start from intuition and design a method, or
  2) Start from data and use Machine Learning, or
  3) Start from LOTS of data and use Deep Learning
- Machine Learning problems belong to one of these types:
  1) Regression,
  2) Classification, or
  3) Clustering.

References

[1] Computer Vision: Algorithms and Applications, R. Szeliski (http://szeliski.org/Book)

[2] Learning OpenCV 3, A. Kaehler & G. Bradski

- Available online through Safari Books, Seneca libraries
- https://senecacollege-primo.hosted.exlibrisgroup.com/primo-explore/fulldisplay?docid=01SENC_ALMA5153244920003226&context=L&vid=01SENC&search_scope=default_scope&tab=default_tab&lang=en_US

[3] Practical introduction to Computer Vision with OpenCV, Kenneth Dawson-Howe

- Available through Seneca libraries
- https://senecacollege-primo.hosted.exlibrisgroup.com/primo-explore/fulldisplay?docid=01SENC_ALMA5142810950003226&context=L&vid=01SENC&search_scope=default_scope&tab=default_tab&lang=en_US

[4] Applied Predictive Analytics: Principles and Techniques for the Professional Data

Readings

Chapter 10 [2]

Chapter 20 to 22 [2]

- [1] **A Practical Introduction to Computer Vision with OpenCV** by Kenneth Dawson-Howe Available online via library.senecacollege.ca: Permalink
- [2] **Learning OpenCV 4 Computer Vision with Python 3** by J. Howse & J. Minichino Available online via library.senecacollege.ca: Permalink
- [3] **Learning OpenCV 3** by A. Kaehler & G. Bradski Available online via library.senecacollege.ca: Permalink [4] **Mastering OpenCV with practical computer vision projects** by D.L. Baggio et al. Available online via library.senecacollege.ca: Permalink