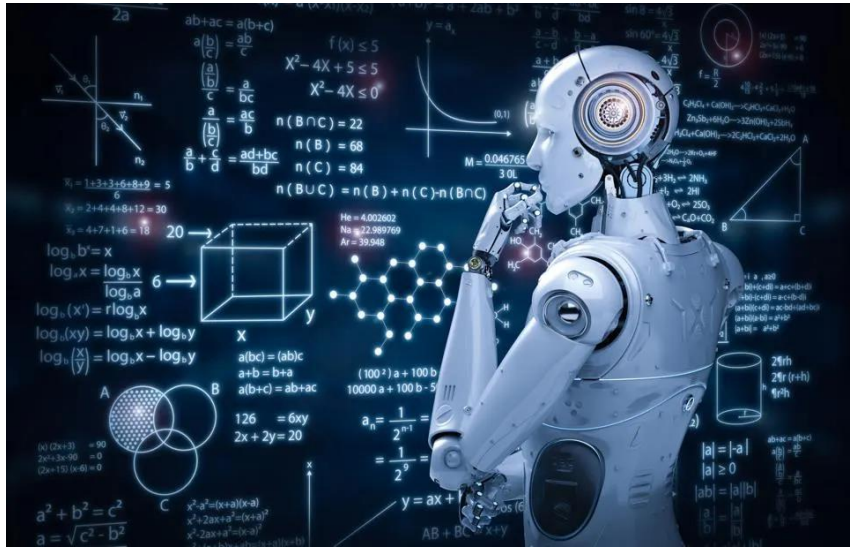
Machine Learning for BioRobotics



Credit: Why Machine Learning Needs Semantics Not Just Statistics article on www.forbes.com

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Syllabus

- Tentative Topics:
  - Introduction to Machine Learning (ML).
  - Python Programming.
  - Popular Python packages for ML.
  - Supervised Learning Algorithms.
  - Unsupervised Learning Algorithms.
  - Classification, Regression, and Clustering.
  - Overfitting and Underfitting.
  - Dimensionality Reduction.
  - Feature Selection.

- Final Project: Implementation of a research article.

Syllabus

- Textbooks:
  - Machine Learning, Tom Mitchell, McGraw Hill, 1997.
  - S. Theodoridis and K. Koutroumbas, Pattern Recognition, Academic Press 4th Edition.

What is Machine Learning?

Definition: "A computer program is said to learn from experience *E* with respect to some class of tasks *T* and performance measure *P*, if its performance at tasks in *T*, as measured by *P*, improves with experience *E*."

Tom Mitchell, 1997.

Example:

A handwriting recognition learning problem:

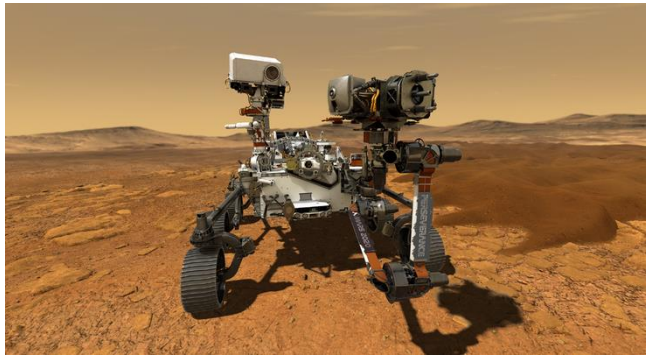
- Task *T*: recognizing and classifying handwritten words within images.
- Performance measure *P*: percent of words correctly classified.
- Training experience *E*: a database of handwritten words with given classifications.

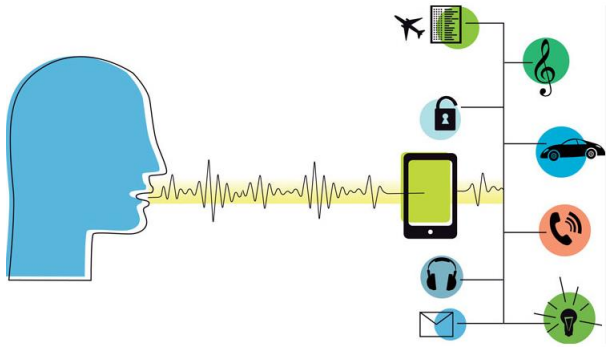
- Traditional programming is a more fixed approach where the programmer designs the solution explicitly, while ML is a more flexible and adaptive approach where the ML model learns from data to generate a solution (different approaches to problem solving).

Why Machine Learning?

Learning can be used for the following cases:

- Human expertise does not exist (navigating on Mars)
- Humans are unable to explain their expertise (speech recognition)
- Humans are required to analyze massive amounts of data (Genomics and Personalized Medicine)
- Other



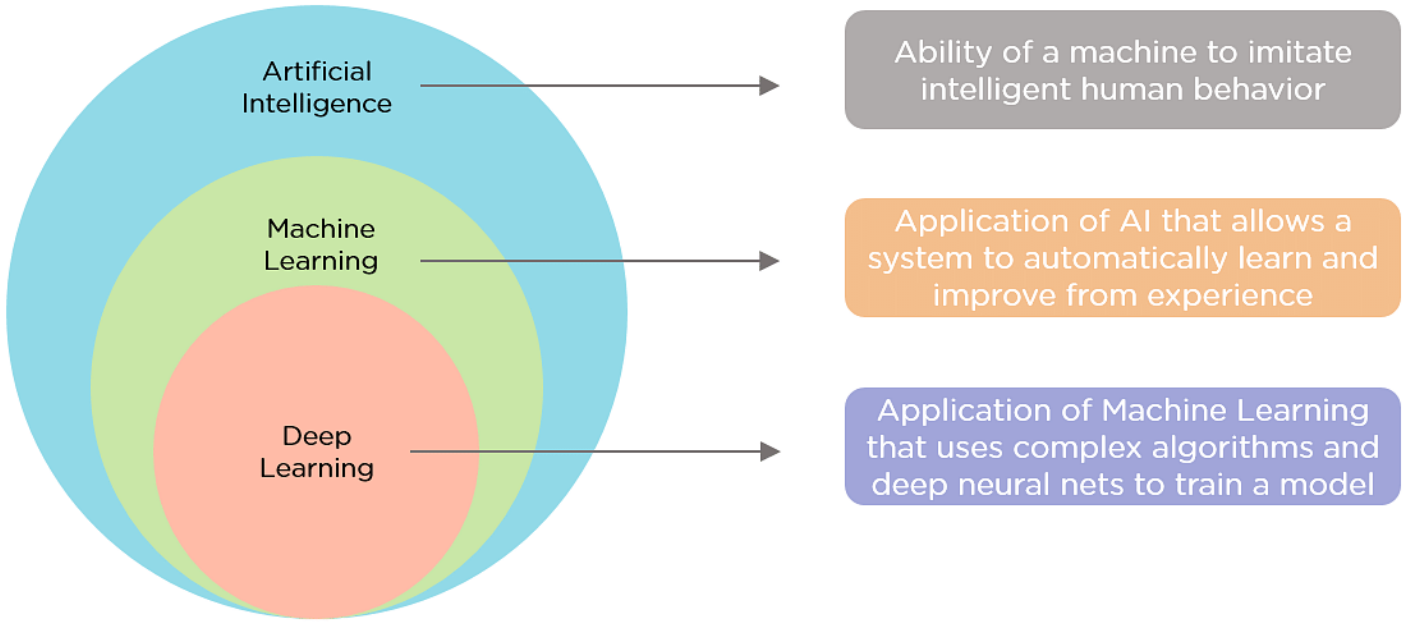


ML is not always suitable for the given task:

- For example, learning to calculate salaries for employees.

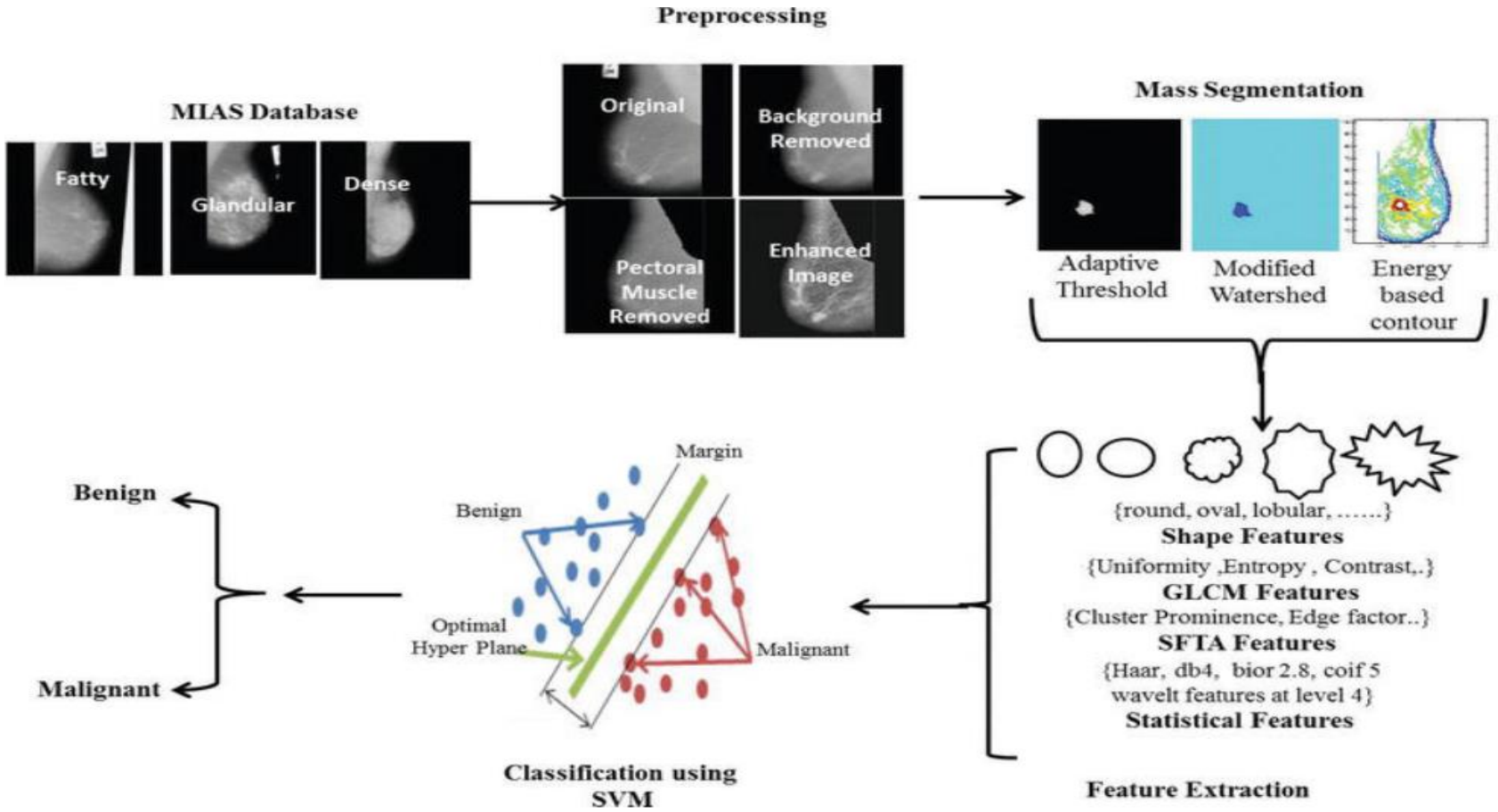
Artificial Intelligence(AI), Machine Learning, and Deep Learning

- Artificial intelligence is the overarching concept of machines performing intelligent tasks.
- Machine learning is a subset of AI that involves algorithms learning from data.
- Deep learning is a subset of machine learning that utilizes deep neural networks to learn complex patterns and representations from data.



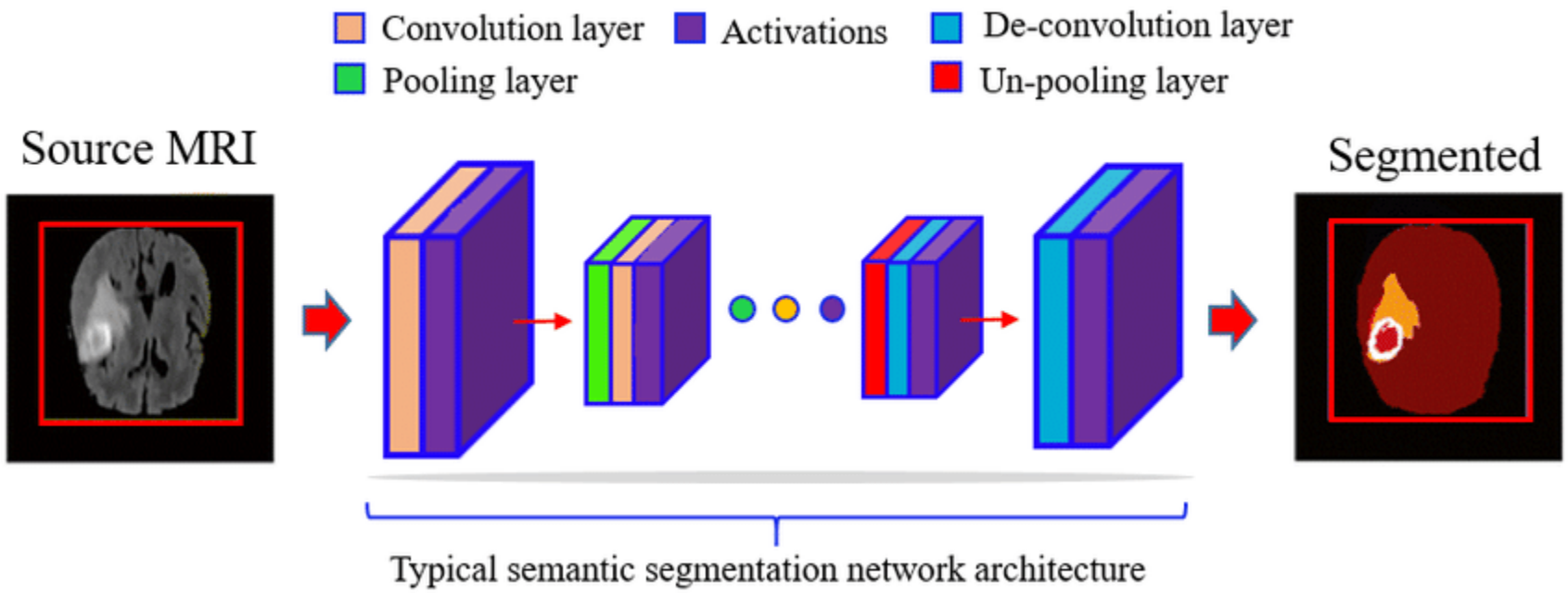
Applications of Machine Learning in the Biomedical Engineering Field.

Image Classification



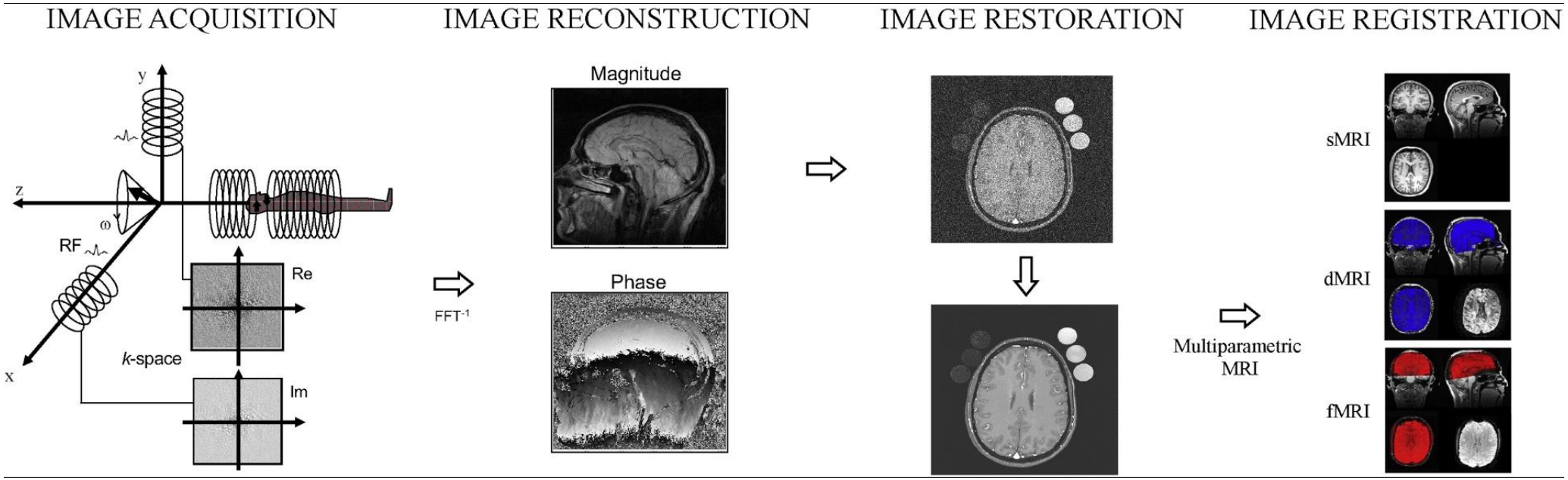
Kirilov, Kiril & Borovska, Plamenka. (2019). Conceptual model of integrated approach for in silico knowledge data discovery for breast cancer diagnostics and precision therapy. AIP Conference Proceedings. 2172. 020003. 10.1063/1.5133485.

Image Segmentation



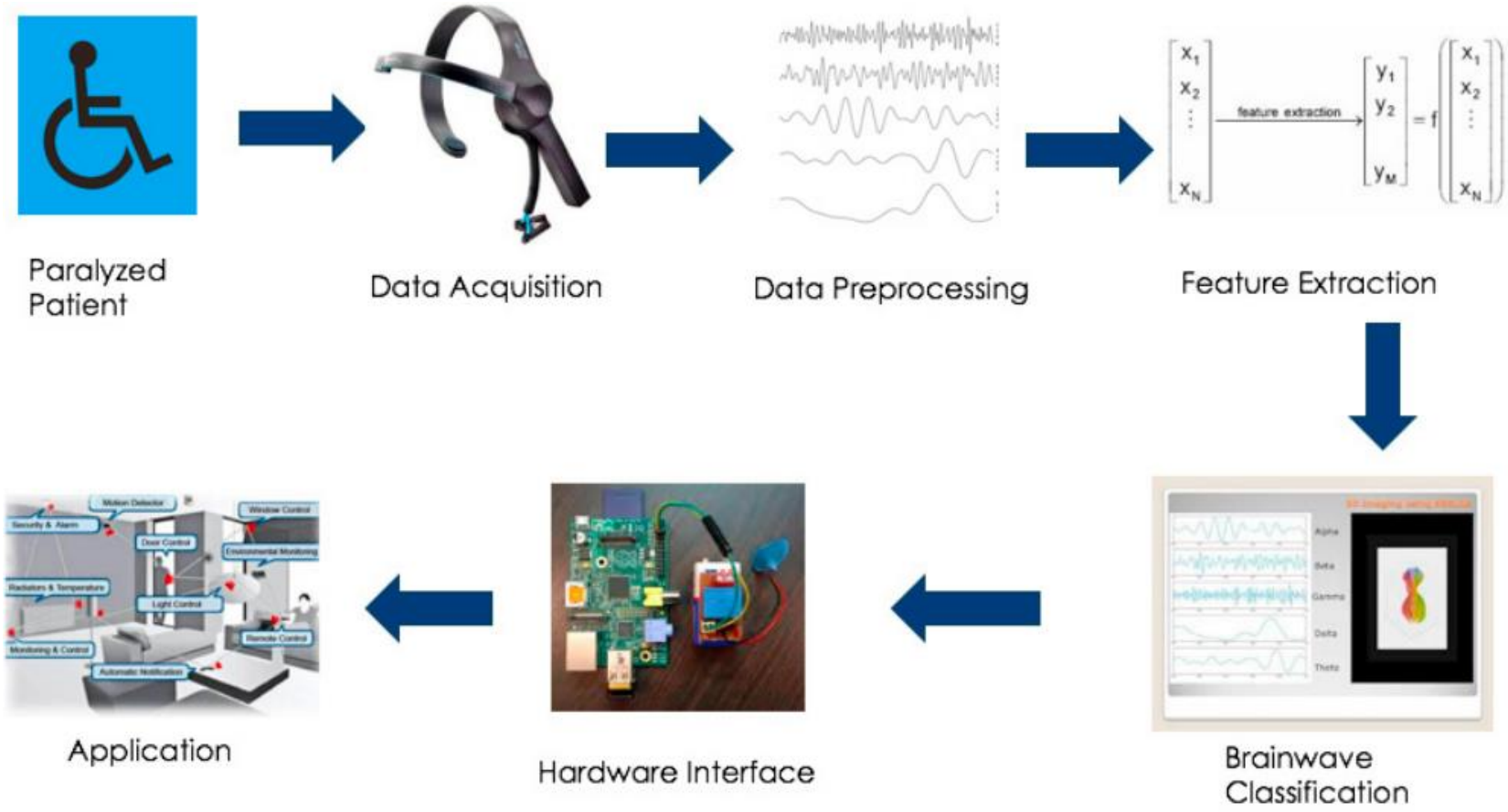
Altaf, Fouzia & Islam, Syed & Akhtar, Naveed & Janjua, Naeem. (2019). Going Deep in Medical Image Analysis: Concepts, Methods, Challenges and Future Directions. IEEE Access. PP. 1-1. 10.1109/ACCESS.2019.2929365.

Also, Image Reconstruction, Restoration, and Registration



Alexander Selvikvåg Lundervold, Arvid Lundervold, An overview of deep learning in medical imaging focusing on MRI, Zeitschrift für Medizinische Physik, Volume 29, Issue 2, 2019, Pages 102-127, ISSN 0939-3889,

Brain Computer Interface (BCI)



Damodar Reddy Edla, Kunal Mangalorekar, Gauri Dhavalikar, Shubham Dodia, Classification of EEG data for human mental state analysis using Random Forest Classifier, ProcediaComputer Science, Volume 132, 2018, Pages 1523-1532.

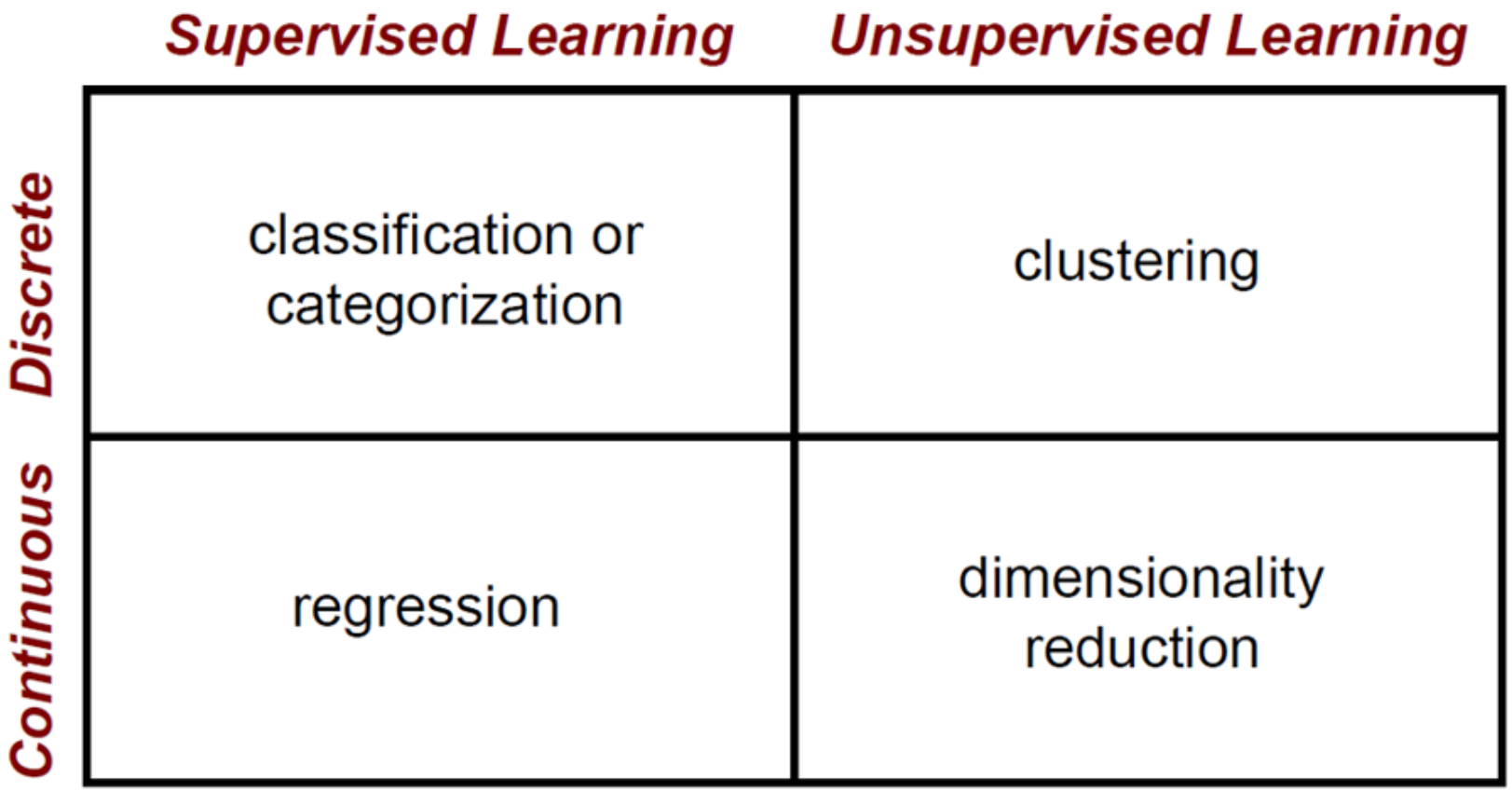
Types of Learning

- Supervised learning:
  - The labels or correct outputs are included in the training data.
  - Common Tasks: Regression and Classification
  - Algorithms: Linear Regression, Logistic Regression, KNN Classifier, Decision Trees, Random Forests, Support Vector Machines, Naïve Bayes Classifier, Neural Networks.

- Unsupervised learning:
  - The labels or correct outputs are not included in the training data.
  - Common Tasks: Clustering
  - Algorithms: K-means Clustering, Hierarchical Clustering.

- Reinforcement learning:
  - Rewards from sequence of actions.

Machine Learning Problems



Supervised Learning: Regression

- Housing price prediction using linear regression:

Classification

- Apply a prediction function to a feature representation of the image/input data to get the desired output:

- Note: The data here is images but it can be signal or any other kind.

Classification

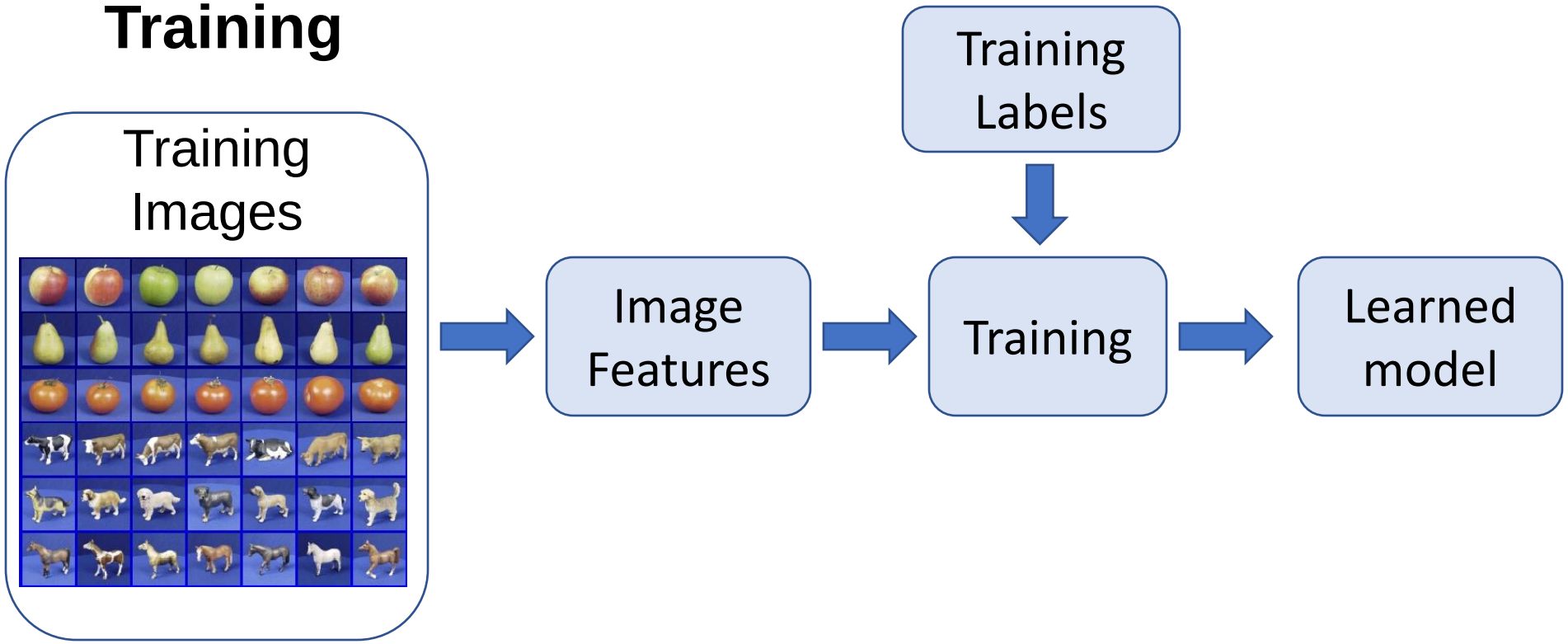
$$y = f(\mathbf{x})$$

output — prediction function — Image feature

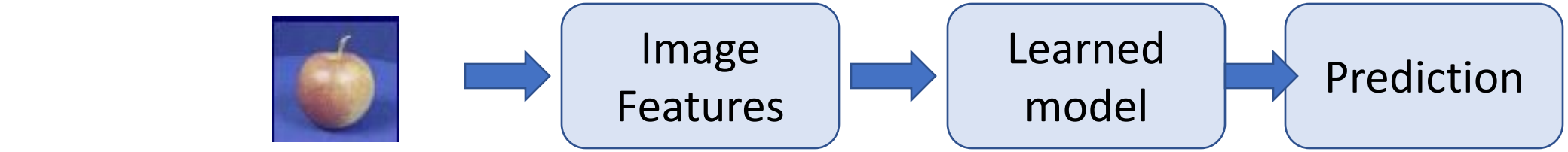
- **Training:** given a *training set* of labeled examples $\{(\mathbf{x}_1, y_1), \ldots, (\mathbf{x}_N, y_N)\}$, estimate the prediction function f by minimizing the prediction error on the training set
- **Testing:** apply f to a never before seen *test example* $\mathbf{x}$ and output the predicted value $y = f(\mathbf{x})$

Steps

Training

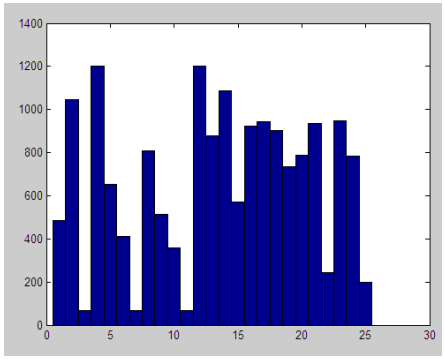


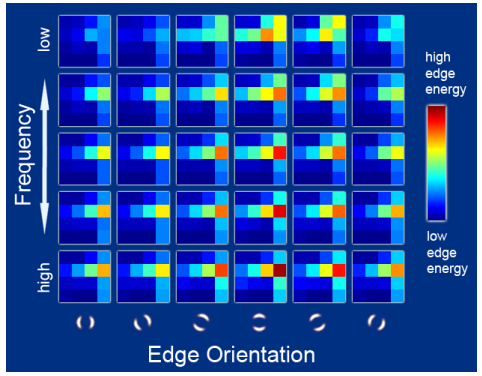
Testing



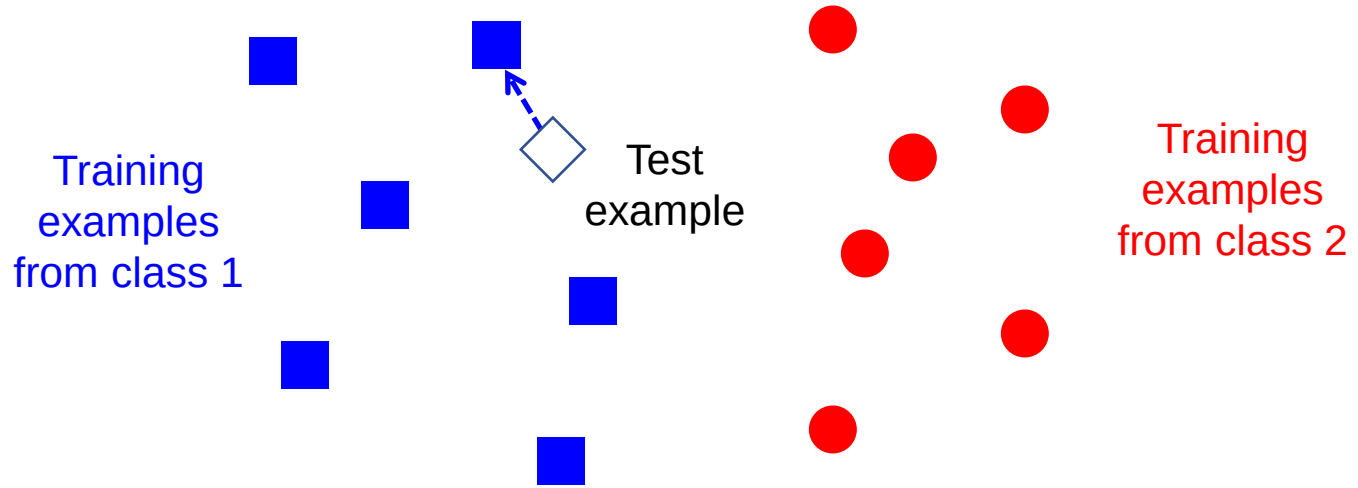
Features

- Raw pixels
- Histograms
- GIST descriptors
- …….





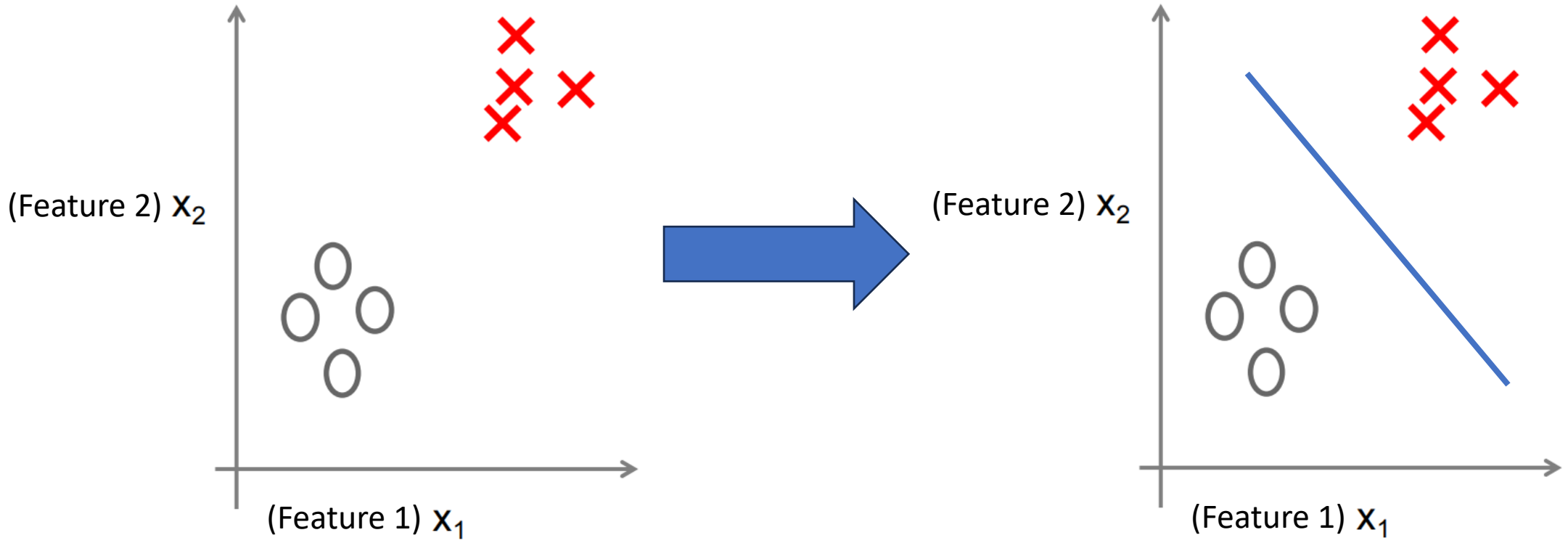
Classifiers: Nearest Neighbor Classifier



f(**x**) = label of the training example nearest to **x**

- All we need is a distance function for our inputs
- No training required!

Classifiers: Linear Classifier

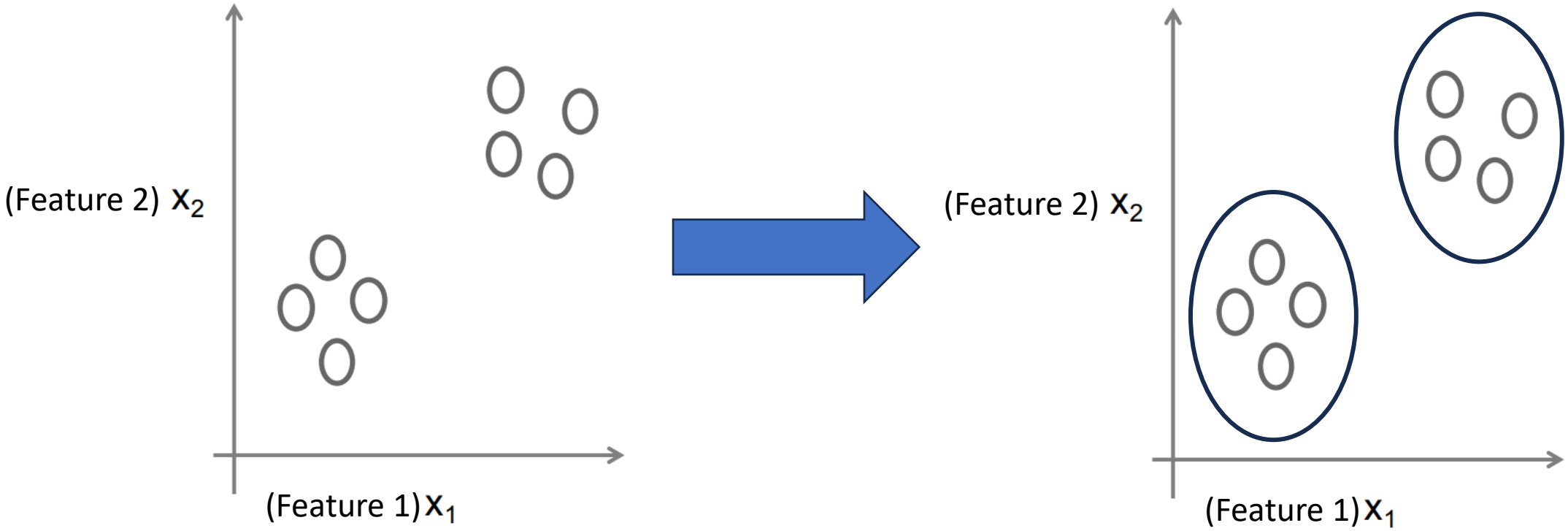


Notice: There are labels

Find a *linear function* to separate the classes:

$f(\mathbf{x}) = \text{sign}(\mathbf{w} \cdot \mathbf{x} + b)$

Unsupervised Learning: Clustering

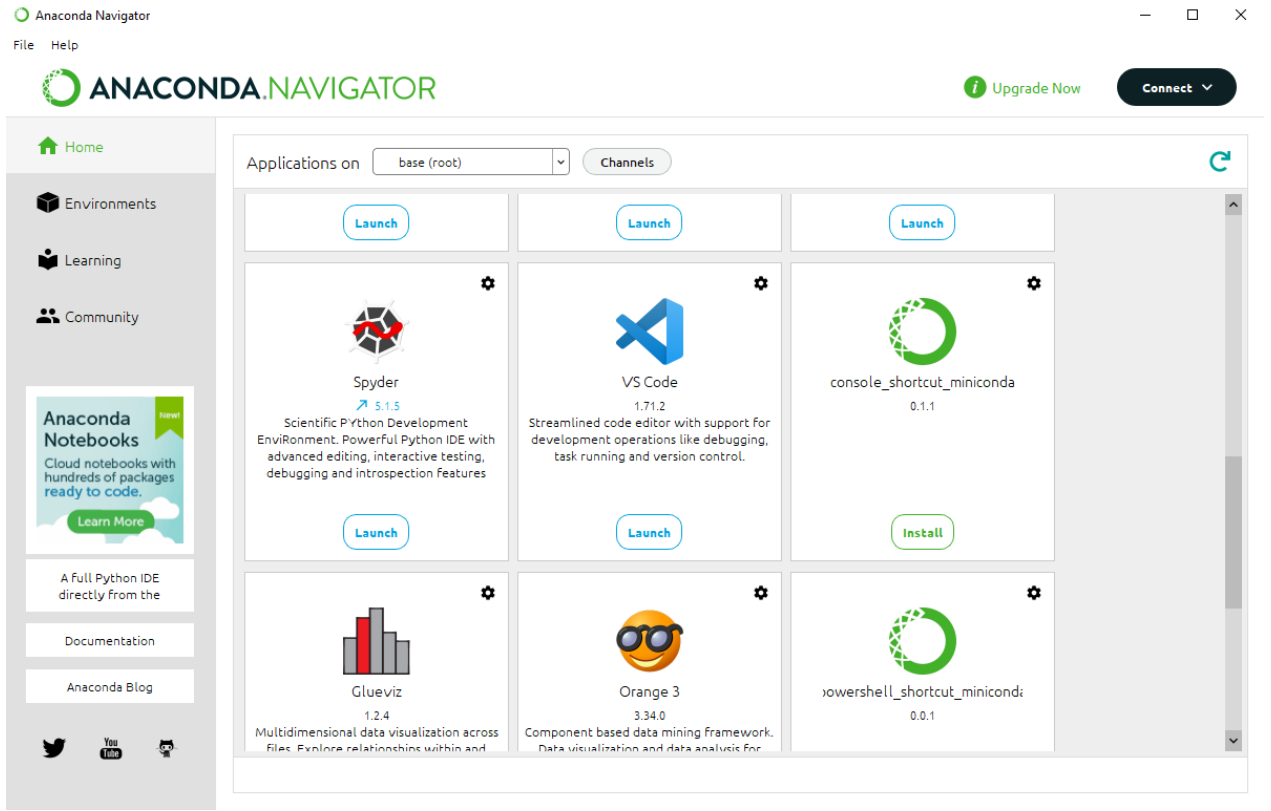


Notice: There are no labels

Python Programming Language (https://www.python.org/)

- Python is a high-level, general-purpose programming language. Its design philosophy emphasizes code readability with the use of significant indentation. Python is dynamically typed and garbage-collected. It supports multiple programming paradigms, including structured, and object-oriented paradigms.

- Python Installation:
  1. Download and install Anaconda platform from (https://www.anaconda.com/download)
  1. Run Anaconda Navigator from start menu.
  2. Install Spyder IDE
  3. Launch Spyder IDE



- Write and execute Python in your browser:
  - No installation required
  - https://colab.research.google.com

Python Data Types

```
#Python is dynamically typed
x = 100
#Print the value of x using the print function
print(x)
```

```
100
```

```
#Everything is represented as object
print(type(x))
```

```
<class 'int'>
```

```
#Multiplication
x = 100 * 2
print(x)
```

```
200
```

```
#Multiplication (another way)
x *= 2
print(x)
```

```
400
```

```
#Addition
x += 100
print(x)
```

```
500
```

```
#Subtraction
x -= 100
print(x)
```

```
400
```

```
#Division
x /= 10
print(x)
```

```
40.0
```

```
#Datatype changed to float due to division
print(type(x))
```

```
<class 'float'>
```

```
#Convert the number back into integer
x = int(x)
print(type(x))
```

```
<class 'int'>
```

```
#Raise x to the power 2
x = x**2
print(x)
```

```
1600
```

```
#Another way
x **= 2
print(x)
```

```
2560000
```

Python Data Types

(Strings)

```
str1 = "Cairo"
str2 = " "
str3 = 'University'
#Concatenate Strings
str4 = str1 + str2 + str3
print(str4)
```

```
Cairo University
```

```
#Concatenate strings and numbers with formatted output
str5 = '%s%s%s %d' % (str1, str2, str3, 2024)
print(str5)
```

```
Cairo University 2024
```

```
#Convert an integer to string using str()
str6 = '%s%s%s %s' % (str1, str2, str3, str(2024))
print(str6)
```

```
Cairo University 2024
```

```
print(type(str6))
```

```
<class 'str'>
```

```
#Strings are objects, so you can execute methods(functions)
#on strings. Use replace method to replace strings.
str7 = str6.replace('2024', '1990')
print(str7)
```

```
Cairo University 1990
```

```
print(str6)
```

```
Cairo University 2024
```

```
#Again stings are objects. Here, we use the upper method
#to convert the letters into upper case.
print(str6.upper())
```

```
CAIRO UNIVERSITY 2024
```

```
#Convert to lower case.
str6 = str6.lower()
print(str6)
```

```
cairo university 2024
```

```
#Format a string using format method wher we do not
#have to know the data type of the variables.
str8 = "{} {}".format("BMES", "Department")
print(str8)
```

```
BMES Department
```

```
#Using escape sequence \n Linefeed
print("Cairo\nUniversity")
```

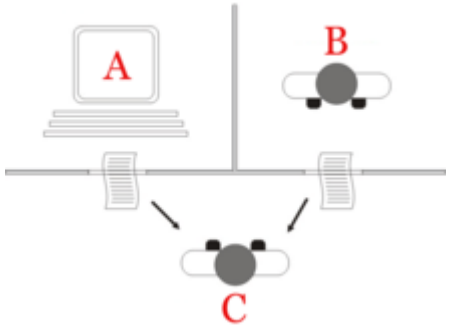
```
Cairo
University
```

```
#Using escape sequence \t TAB
print("\tCairo\nUniversity")
```

```
	Cairo
University
```

History of Machine Learning

- 1943: The first mathematical model of neural networks presented by Walter Pitts and Warren McCulloch.
- 1950: Alan Turing created the Turing Test to determine if a computer has real intelligence.
- 1952: Arthur Samuel The first ever computer learning program (game of checkers).
- 1957: Frank Rosenblatt designed the first neural network for computers - the perceptron – which simulated the thought processes of the human brain.



- 1967: “nearest neighbor” algorithm was written
- 1979: students at Stanford University invent the ‘Stanford Cart’ which could navigate obstacles in a room on its own.
- 1997: IBM’s Deep Blue shocked the world by beating the world champion at chess.
- 2006: The term “deep learning” was coined by Geoffrey Hinton to explain new algorithms that let computers “see” and distinguish objects and text in images and videos.
- 2010: Microsoft revealed their Kinect technology could track 20 human features at a rate of 30 times per second, allowing people to interact with the computer via movements and gestures.

History of Machine Learning

- 2011: Google Brain was developed, and its deep neural network could learn to discover and categorize objects much the way a cat does.
- 2014: Facebook developed DeepFace, a software algorithm that is able to recognize or verify individuals on photos to the same level as humans can.
- 2015: Amazon launched its own machine learning platform.
- 2016: Google’s artificial intelligence algorithm beat a professional player at the Chinese board game Go, which is considered the world’s most complex board game and is many times harder than chess.
- 2020: Open AI announced a ground-breaking natural language processing algorithm GPT-3 with a remarkable ability to generate human-like text when given a prompt.

Thank You!