MSE491: Application of Machine Learning in Mechatronic Systems

Introduction

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Objectives & Aims

Objectives:

To learn:

- some of the basic mathematical concepts underpinning Machine Learning (ML) algorithms
- different types of machine learning approached including supervised and unsupervised learning algorithms
- ML algorithms in Python (maybe MATLAB as well)
- the implement of a trained ML algorithm on an embedded system

Aims:

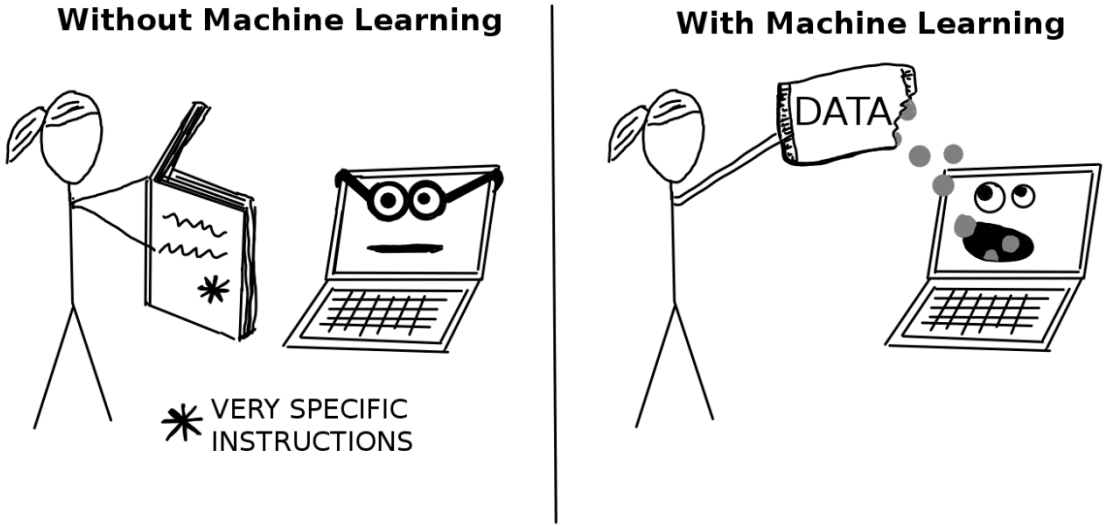
You will learn to:

- explain the strengths and limitations of the various machine learning algorithms
- evaluate ML methods performance and select a proper one for your data
- perform and implement a trained ML model on an embedded platform

What is the meaning of "Machine Learning"?

- ML is a category of algorithm that allows software applications to become more accurate in predicting outcomes without being explicitly programmed

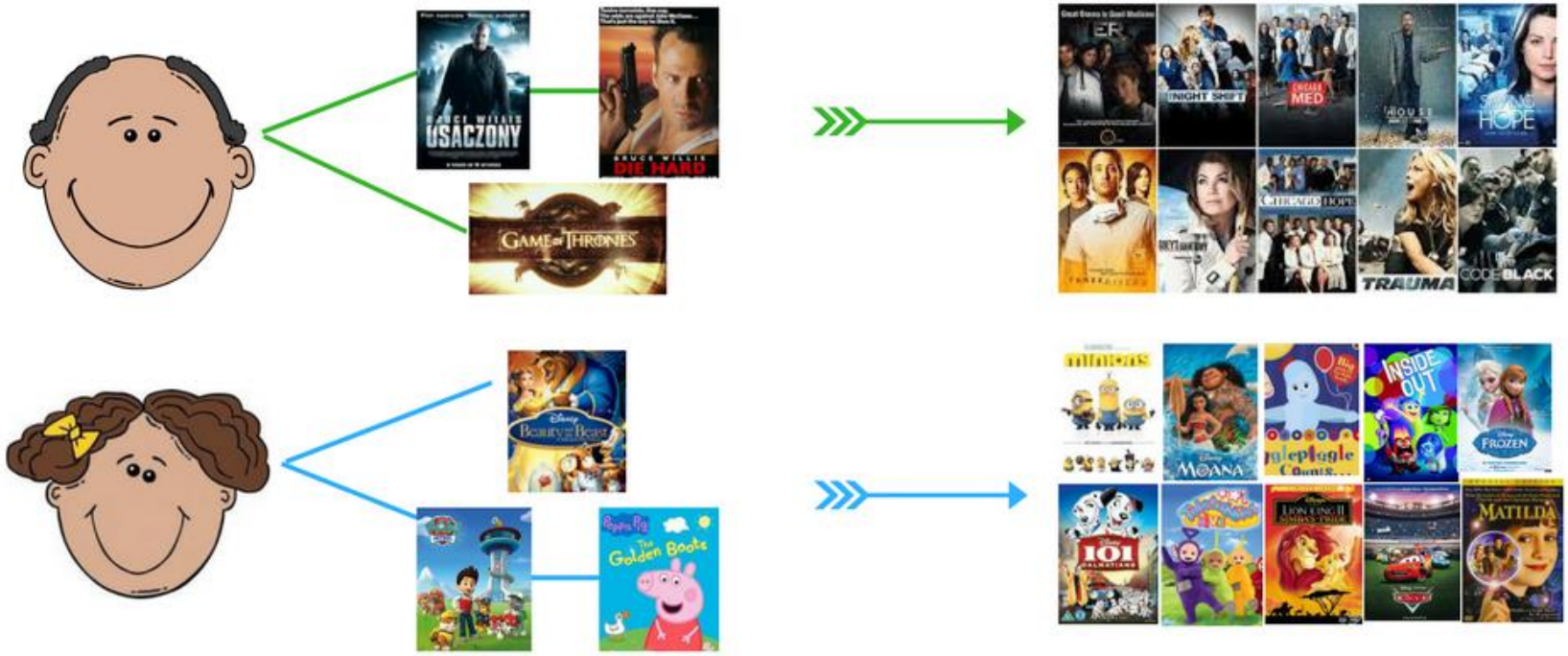
- The basic premise of ML is to build algorithms that can receive input data/experience and use statistical analysis to predict an output. Building such a model helps *a precise approximation* of outputs using new data.



What is the meaning of "Machine Learning"?

- Examples in industries:

  Netflix: Making suggestions to Viewers based on their previous choice (input: Customer transactions => output: consumer behavior/selection)

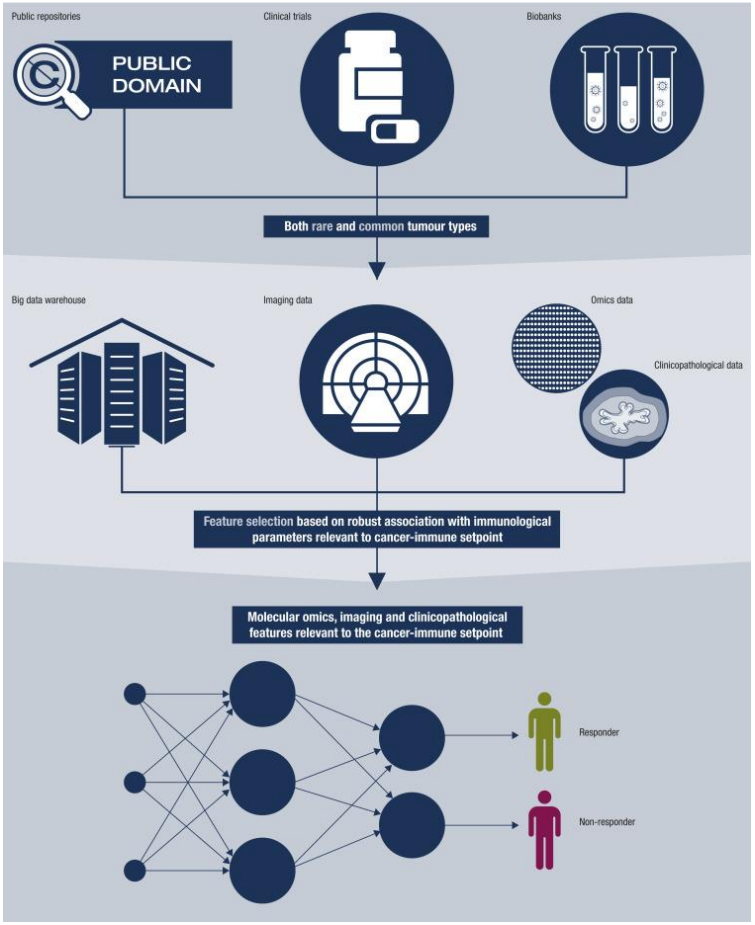


What is the meaning of “Machine Learning”?

- Examples in industries:

  Pfizer: modification of immune system's ability to help fight cancer.
  input : patient’s immune system structure

  output: how well the immune system can recognize and treat cancer cells



https://www.sciencedirect.com
by Hooiveld-Noeken *et. al.*

When to use Machine Learning?

- A system driven by ML algorithms can learn to
  - make decisions
  - adapt to its environment

- ML is used when:
  - Humans are unable to explain a system's behavior (retail customer behavior)
  - Solution needs to be adapted to particular cases (personalized medicine)

- There is no need to "learn" to calculate payroll!!

What is inside a Machine Learning algorithm?

- Statistics: Inference from a sample
- Optimization: a performance criterion evaluation using example data (experience)
- Computer science: efficient algorithms to
  - Solve the optimization problem
  - Representing and evaluating the model for inference

Applications

- Retail: Customer relationship management (CRM)
- Finance: fraud detection, market prediction
- Manufacturing: Control, robotics, troubleshooting
- Medicine: Medical diagnosis
- Web mining: Search engines
- ...

Main Area of Applications

- Learning Associations
- Supervised Learning
  - Classification
  - Regression
- Unsupervised Learning
  - Clustering
  - Non-clustering
- Reinforcement Learning

Learning Associations

- Association rules analysis is a technique to uncover how items are associated to each other.
- To understand consider items X and Y frequently bought together:
  - Both X and Y can be placed on the same shelf, so that buyers of one item would be prompted to buy the other.
  - Promotional discounts could be applied to just one out of the two items.
  - Advertisements on X could be targeted at buyers who purchase Y.
  - X and Y could be combined into a new product, such as having Y in flavors of X.

Learning Associations

- Basket analysis:

  $P(Y \mid X)$: probability that somebody who buys X also buys Y where X and Y are products/services.

  Example: P (camera | case) = 0.8

  Example: the rule {onions,potatoes} => {burger}

  found in the sales data of a supermarket would indicate that:

  if a customer buys onions and potatoes together, they are likely to also buy hamburger meat. Such information can be used as the basis for decisions about marketing activities such as, e.g., promotional pricing or product placements.

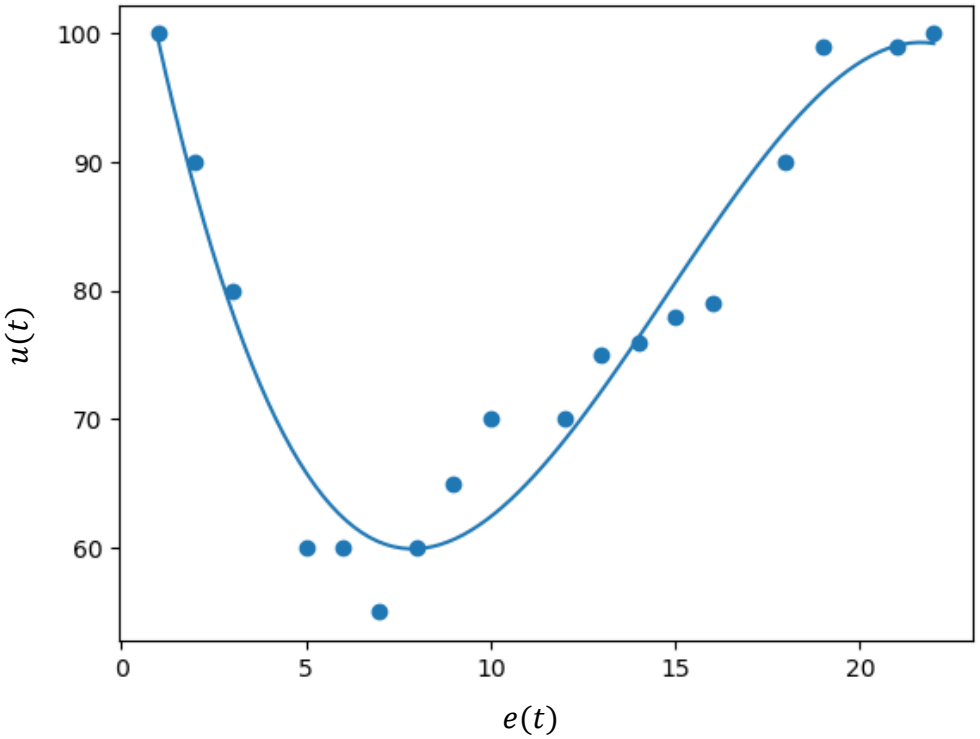
Supervised Learning

- In supervised learning, we are given a data set and already know what our correct output should look like, having the idea that there is a relationship between the input and the output.

- Supervised learning problems are categorized into "regression" and "classification" problems.
  - In a **regression problem**, we are trying to predict results within a continuous output, meaning that we are trying to map input variables to some continuous function.
  - In a **classification problem**, we are instead trying to predict results in a discrete output. In other words, we are trying to map input variables into discrete categories.

Regression Applications

- Given data about the error signal $e(t)$, in a feedback control system, try to predict control signal $u(t)$. The magnitude of control signal $u(t)$ is a continuous function of error signal $e(t)$. This is a regression problem.



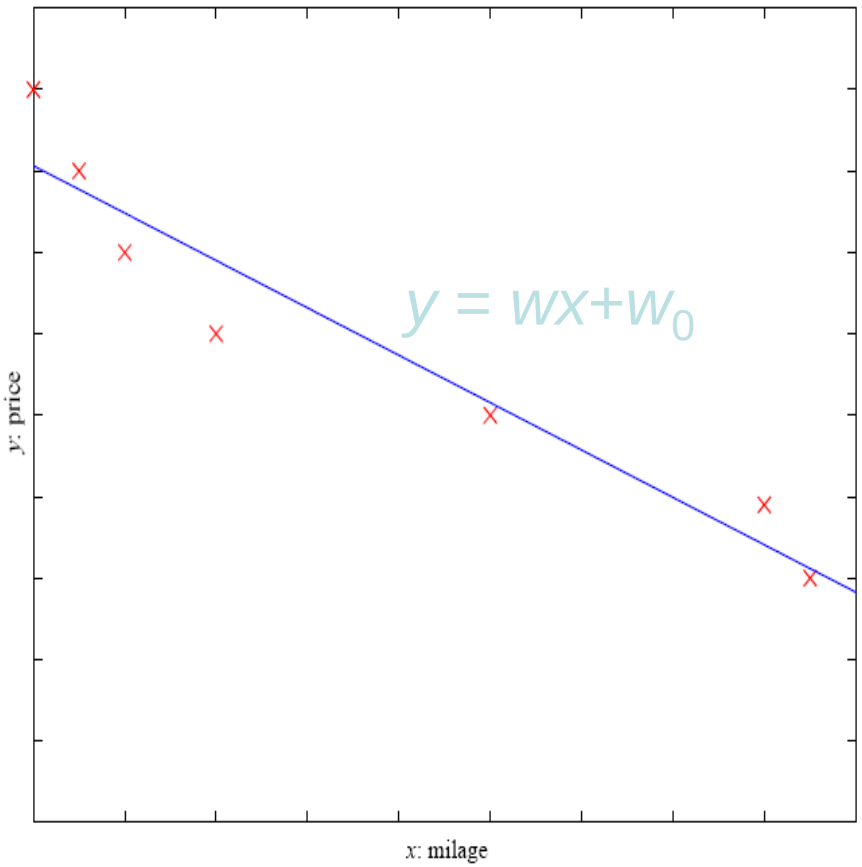
Regression Applications

- Price of a used car
- x : car attributes

  y : price

  $$y = g(x)$$

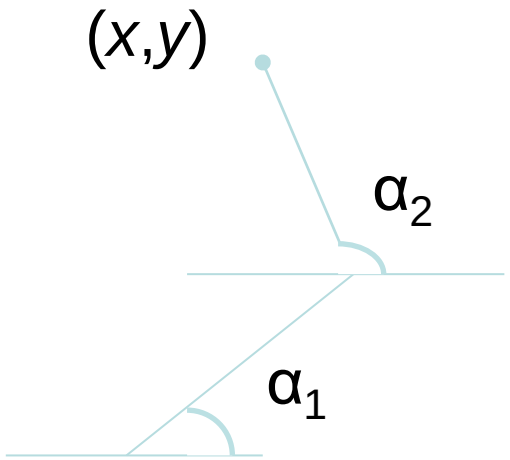
  $g(\ )$: model



Regression Applications

- Navigating a car: Angle of the steering

- Kinematics of a robot arm

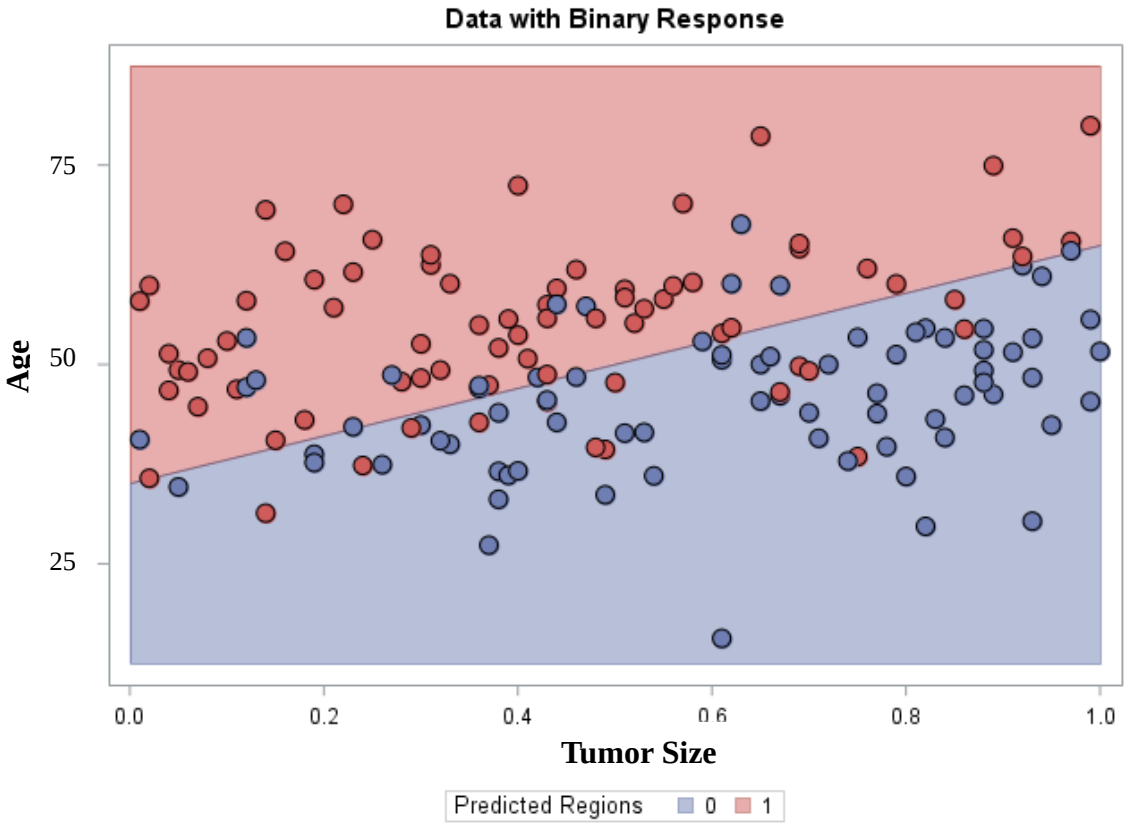


$\alpha_1 = g_1(x,y)$

$\alpha_2 = g_2(x,y)$

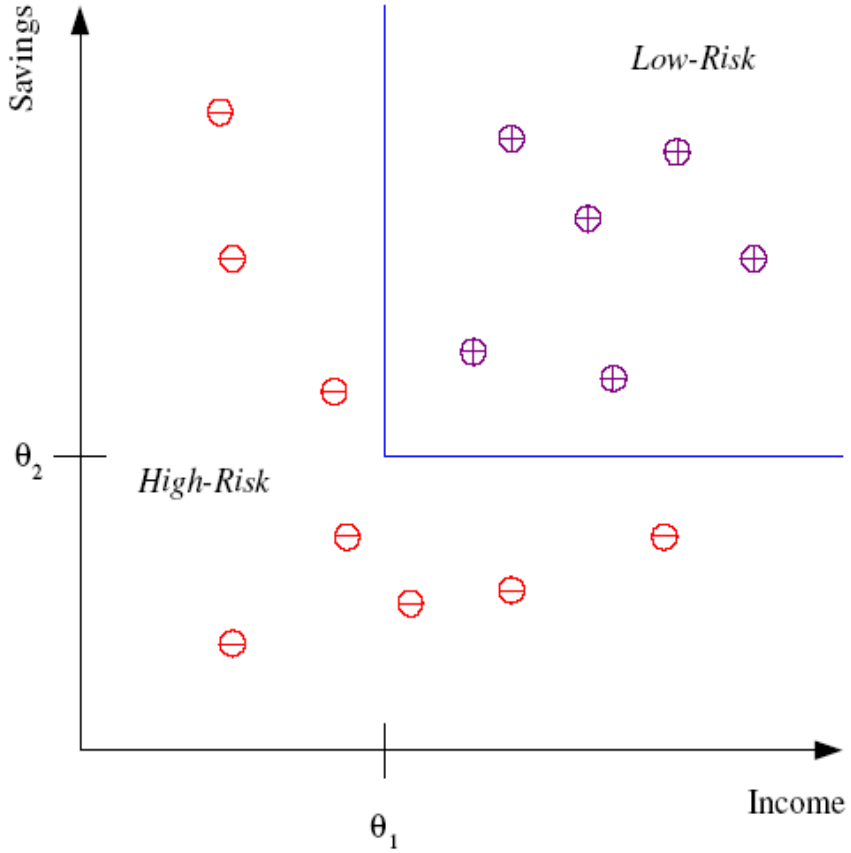
Classification Applications

- Given the information of a patient with a tumor, such as tumor size, patient's age, … predict if the tumor is malignant (1) or benign (0).



Classification Applications

- Example: Credit scoring
- Differentiating between low-risk and high-risk customers from their *income* and *savings*



Discriminant: IF *income* $> \theta_1$ AND *savings* $> \theta_2$

then low-risk

else high-risk

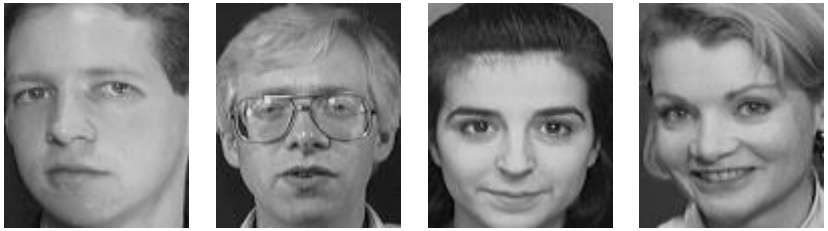
Classification: Some Applications

- Face recognition: Pose, lighting, occlusion (glasses, beard), make-up, hair style
- Character recognition: Different handwriting styles
- Speech recognition: Temporal dependency
- Medical diagnosis: From symptoms to illnesses
- Biometrics: Recognition/authentication using physical and/or behavioral characteristics: Face, iris, signature, etc

Face Recognition

Training examples of a person

Test images



ORL dataset,
AT&T Laboratories, Cambridge UK

Unsupervised Learning

- Unsupervised learning allows us to approach problems with little or no idea what our results should look like. We can derive structure from data where we don't necessarily know the effect of the variables.

- We can derive this structure by clustering the data based on relationships among the variables in the data.

- With unsupervised learning there is no feedback based on the prediction results.

Unsupervised Learning-Examples

- Take a collection of 1,000,000 different genes, and find a way to automatically group these genes into groups that are somehow similar or related by different variables, such as lifespan, location, roles, and so on.

- Customer segmentation in CRM

- Image compression: Color quantization

- Bioinformatics: Learning motifs

Unsupervised Learning-Examples

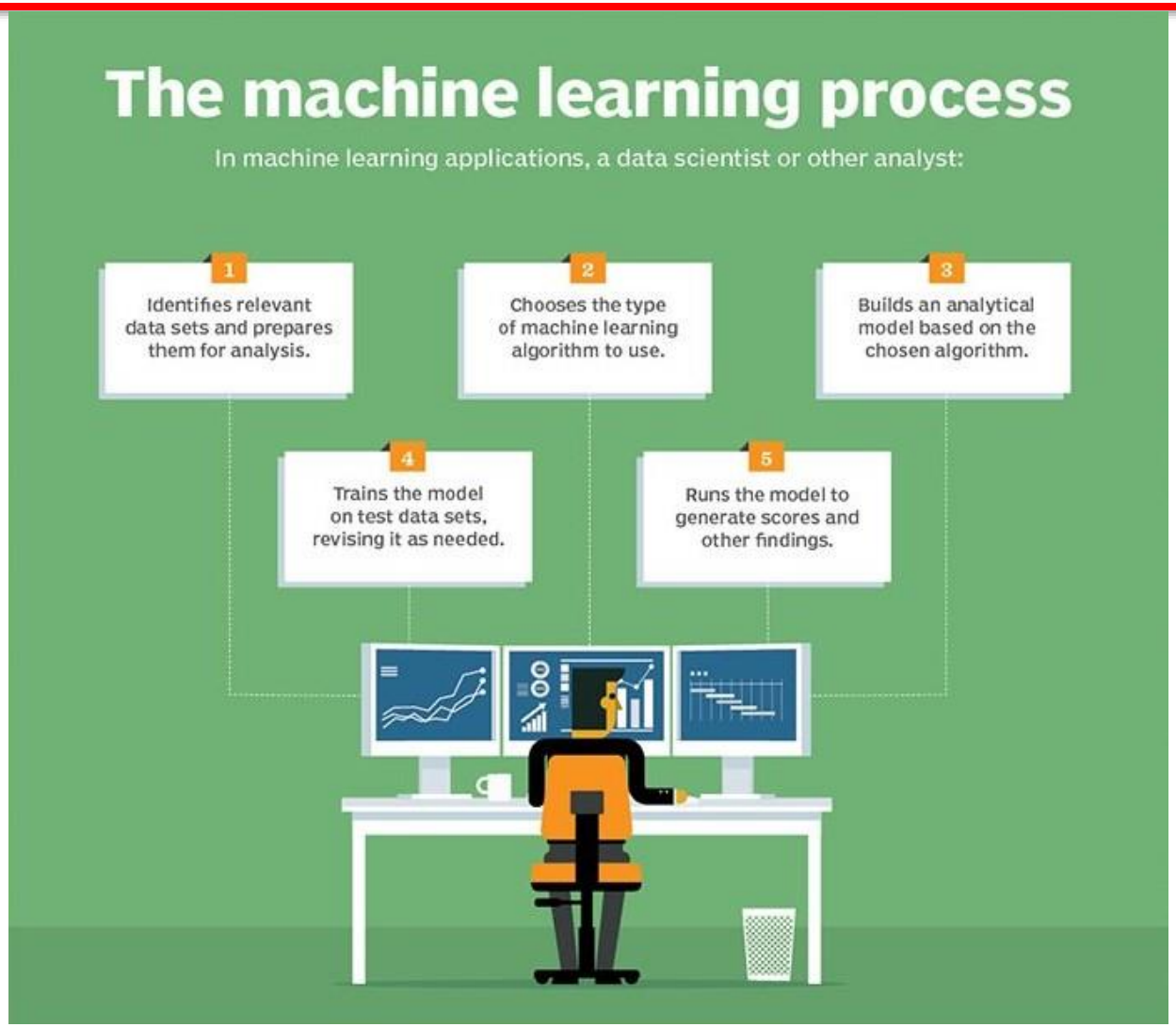
- Non-clustering: The "Cocktail Party Algorithm", allows you to find structure in a chaotic environment. (i.e. identifying individual voices and music from a mesh of sounds at a cocktail party).

- https://www.youtube.com/watch/T0HP9cxri0A

Reinforcement Learning

- Learning a policy: A sequence of outputs
- No supervised output
- Examples:
  - Game playing
  - Robot in a maze

Machine Learning Process



Resources: Journals

- Journal of Machine Learning Research www.jmlr.org
- IEEE Trans on Neural Networks and Learning Systems
- IEEE Trans on Pattern Analysis and Machine Intelligence
- Journals on Statistics/Data Mining/Signal Processing/Natural Language Processing/Bioinformatics/...

Resources: Conferences

- International Conference on Machine Learning (ICML)
- European Conference on Machine Learning (ECML)
- Neural Information Processing Systems (NIPS)
- Uncertainty in Artificial Intelligence (UAI)
- Computational Learning Theory (COLT)
- International Conference on Artificial Neural Networks (ICANN)
- International Conference on AI & Statistics (AISTATS)
- International Conference on Pattern Recognition (ICPR)
- ...