Intelligent systems for industry, supply chain and environment IS4

LESSON 3

Toolboxes, Taxonomy of AI systems and Introduction to sensor in applications




Outline

- Tools
  - How to study this course
  - Prepare your toolboxes (Matalab, Colab, other resources)
- Theory
  - Intelligent systems topics
  - Taxonomy of AI types
  - Main methods presented in the course
  - Deductive and inductive learning
- Overview of AI applied to sensors and environment applications
- **Main points**

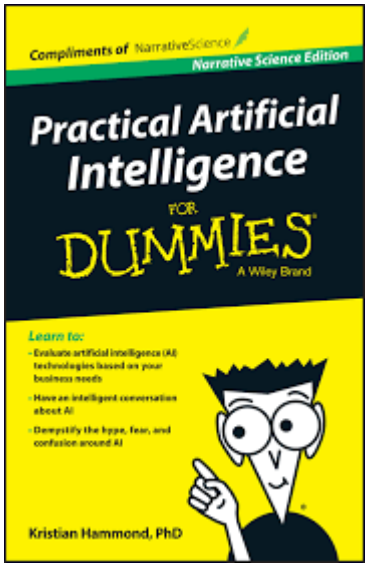



How to study this course?

From superficiality to interiorization

How to learn the AI theory?

Working and designing with "the book" in your hands?



The book really exists,
but please do not buy it…

… or to be hands-free and the knowledge is your backpack?

Real knowledge requires **interiorization!**

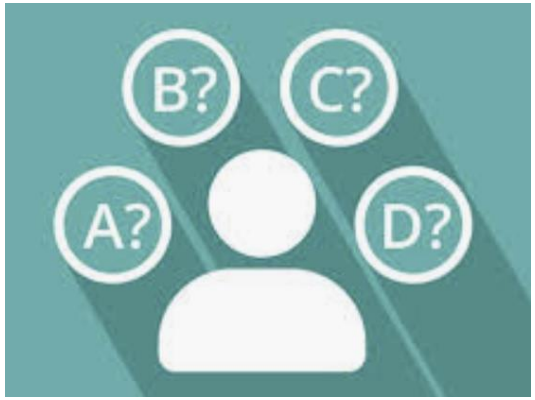
How can I get interiorization?

Especially in the machine learning field you must

1. Study the **theory** and the related **working hypothesis**
2. Study as **many use-cases** as possible to extend your point of view
3. Apply the **theory on real applications**
4. Make a **fair discussion and comparison** every time is possible.
   - Ask you “Why this and not that?”
   - Example: “What is the model really learning?”

How can I get interiorization? (cont.)

- Create your “portfolio” of **models** and **learning methods** (as large as possible)
- **Keep you informed** on the *State Of the Art* (SOA) and the trends
- Always **choose** from different solutions



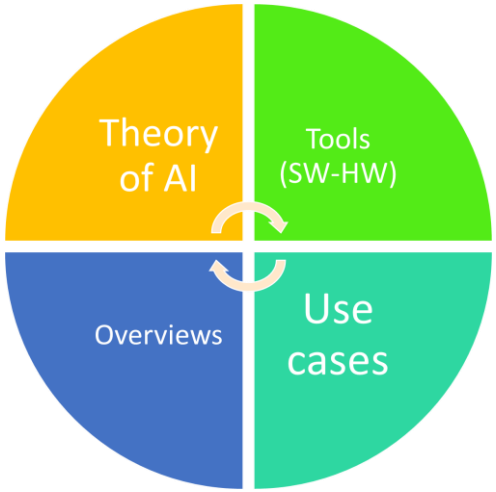
How can I get interiorization? (cont.)

- Do not consider only accuracy
  - There are a wide range of figures of merit to consider in your design (in the next lessons)
- Improving your project by **building on previous experience and discoveries**
  - Standing on the shoulders of giants! The analysis of the SOA is fundamental.




Toolboxes

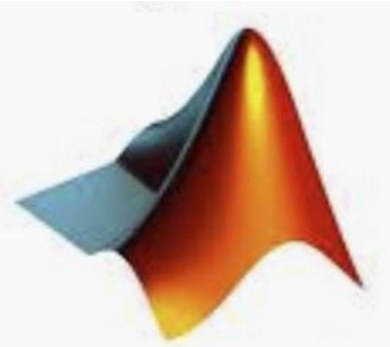
Toolboxes to prepare
for the next lessons



TOOLS

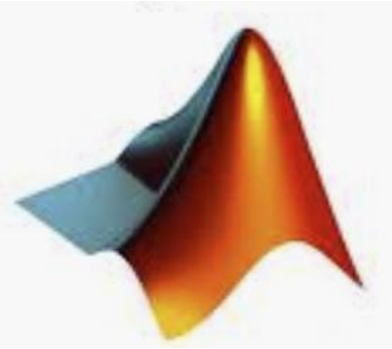
- Few notes just to PREPARE the toolboxes for the next lesson.
- We will review in detail the tools in the next lessons
- Main tools used in the course
  - **Matlab** (many many many tools and functions)
  - **Colab** (Online servers, TPUs, …)
  - **Keras** (The Python Deep Learning library)
- They offer the best tradeoff between *usability* and *complexity*, and a good learning curve.
- Supporting Keras and many NN pretrained models.

TOOL#1: Matlab



- Matlab is the first tool in our course
  - Not only machine learning …. but much much more.
  - Thousands of well-documented and powerful functions
- Read the instruction and download your free license of Matlab as UNIMI student
- Download the last version! The toolboxes are improving fast!
- https://work.unimi.it/servizi/servizi_tec/79539.htm (or just Google>> UNIMI MATLAB)
- See instruction to install MATLAB on an offline machine.

TOOL#1:
Matlab Tooboxes

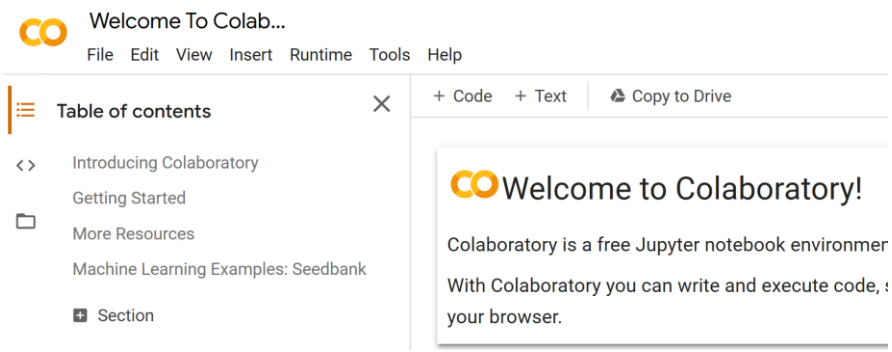


- Install all tooloboxes, but if you are short of space on your PC HD / reduced bandwidth, install just the main toolboxes needed for the course
  - Deep Learning Toolbox
  - Fuzzy Logic Toolbox
  - Statistics and Machine Learning Toolbox
  - Image Processing Toolbox
  - Signal Processing Toolbox
  - Computer Vision Toolbox
  - Choose some toolbox to be used in the future for your projects, it's free!....

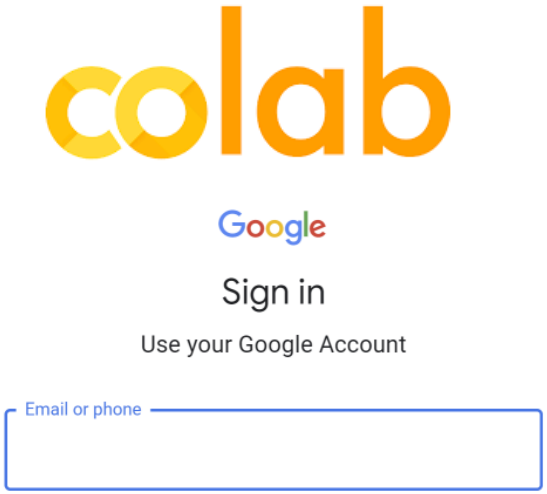
https://it.mathworks.com/products/deep-learning.html

TOOL#2: Google Colab

- COLAB=Colaboratory
  is a free **Jupyter notebook** environment that requires no setup and runs entirely in the cloud.
- You can
  - write and execute code,
  - save and share your analyses,
  - and access powerful computing resources,
  - all for free from your browser.



TOOL#2: Google Colab



- COLAB
  - It is very very useful!
  - It helps us to optimize the time in the course, reaching our goals without wasting time in technicalities
  - But since it requires a google account to save data and code it is **not** strictly compulsory for the course

- You have other options (less easy and ready-to-use)
  - use Matlab instead for all
  - download other local tools (you probably need GPUs) like Jupyter notebook, Ananconda, python, etc.
  - you can create/ use a specific Google Account without any personal information stored in it
  - Do not ask for assistance...

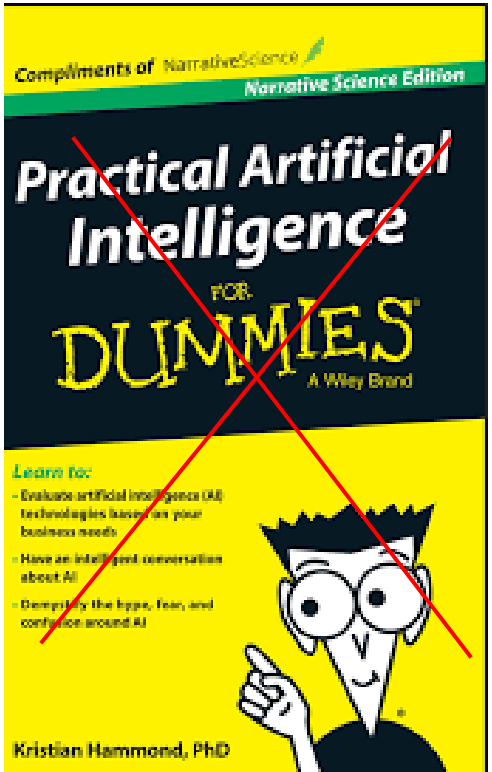
KERAS

- **The Python Deep Learning library**
- A high-level neural networks API, written in Python and capable of running on top of TensorFlow, CNTK, or Thean enabling fast experimentation.
- *From idea to result with the least possible delay*
- *No need to download, it's inside (Matlab, Colab)*

```
from keras.preprocessing import image
from keras.applications import resnet50

# Load Keras' ResNet50 model that was pre-train
model = resnet50.ResNet50()

# Load the image file, resizing it to 224x224 p
img = image.load_img("bay.jpg", target_size=(22

# Convert the image to a numpy array
```

Toolbox #3: P&T Patience and Theory

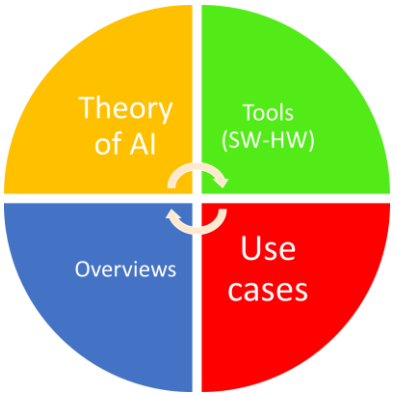
- Since this is not just a «how-to-create-a-neural-network course» or «step-by-step guide to…» we need to face some relevant theory topics before to start the lab/coding activities.



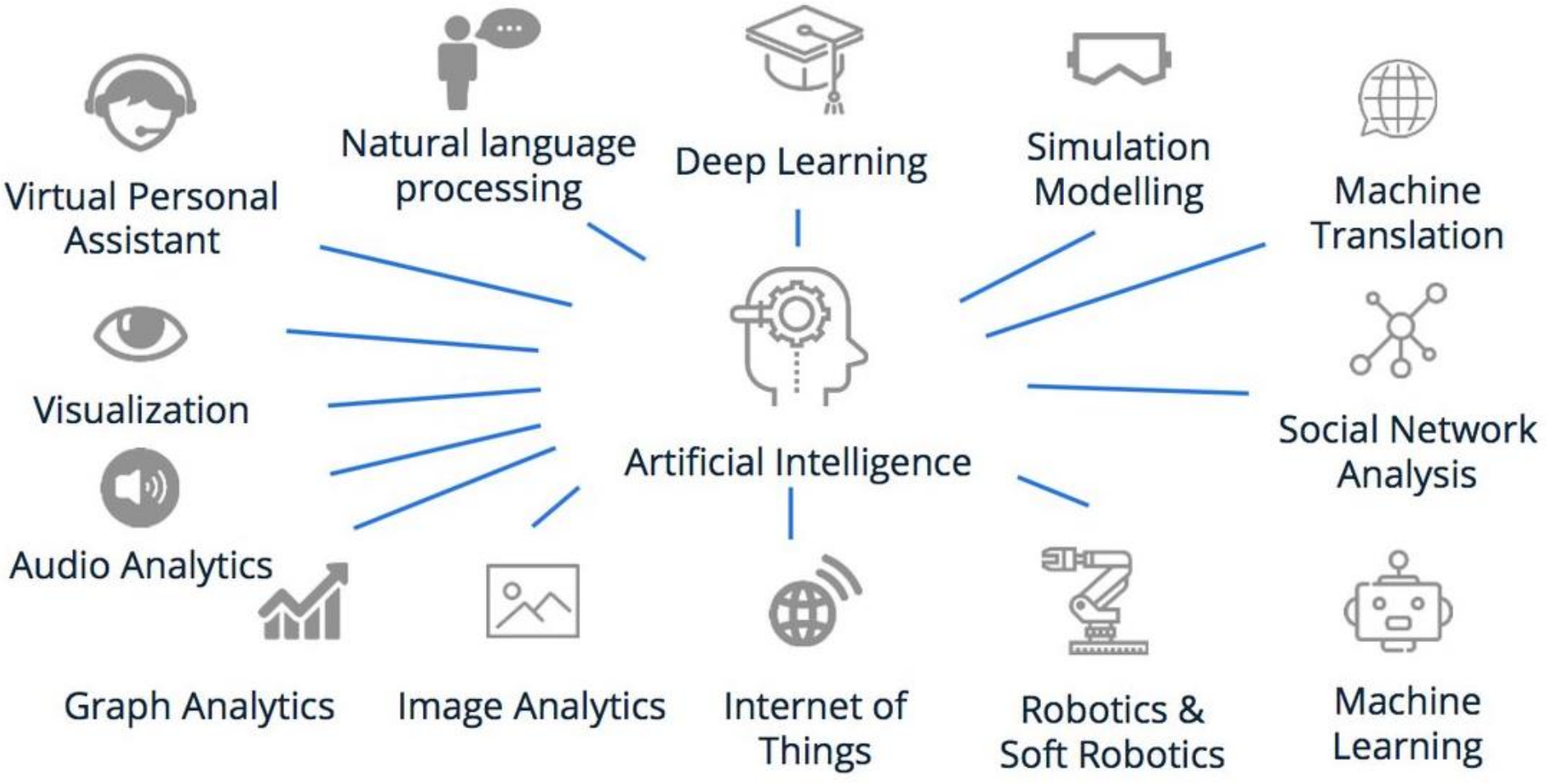
THEORY

Intelligent systems: main types

Many applications but under a general framework



Different topics …

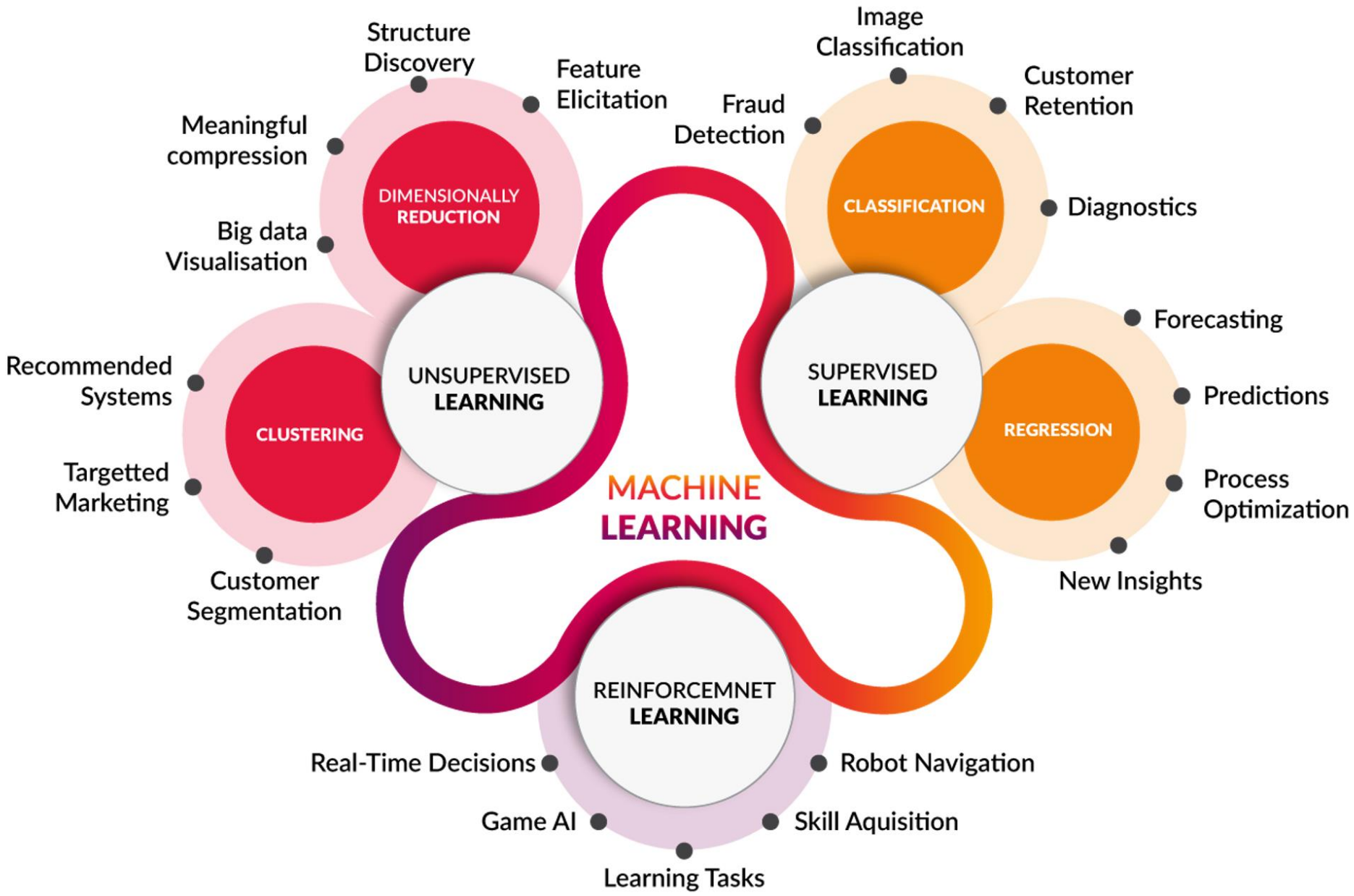


Mimiking what kind of worker?

A common framework?

- So many topics, applications, fields…
- Is there some clever way to **group** and to **cluster** each application of the AI?
- Yes!
  - Let’s study a general taxonomy for AI

ML taxonomy


MACHINE LEARNING
UNSUPERVISED LEARNING
SUPERVISED LEARNING
REINFORCEMNET LEARNING
DIMENSIONALLY REDUCTION
CLUSTERING
CLASSIFICATION
REGRESSION
Structure Discovery
Feature Elicitation
Meaningful compression
Big data Visualisation
Image Classification
Customer Retention
Fraud Detection
Diagnostics
Recommended Systems
Targetted Marketing
Customer Segmentation
Forecasting
Predictions
Process Optimization
New Insights
Real-Time Decisions
Robot Navigation
Game AI
Skill Aquisition
Learning Tasks

ML taxonomy

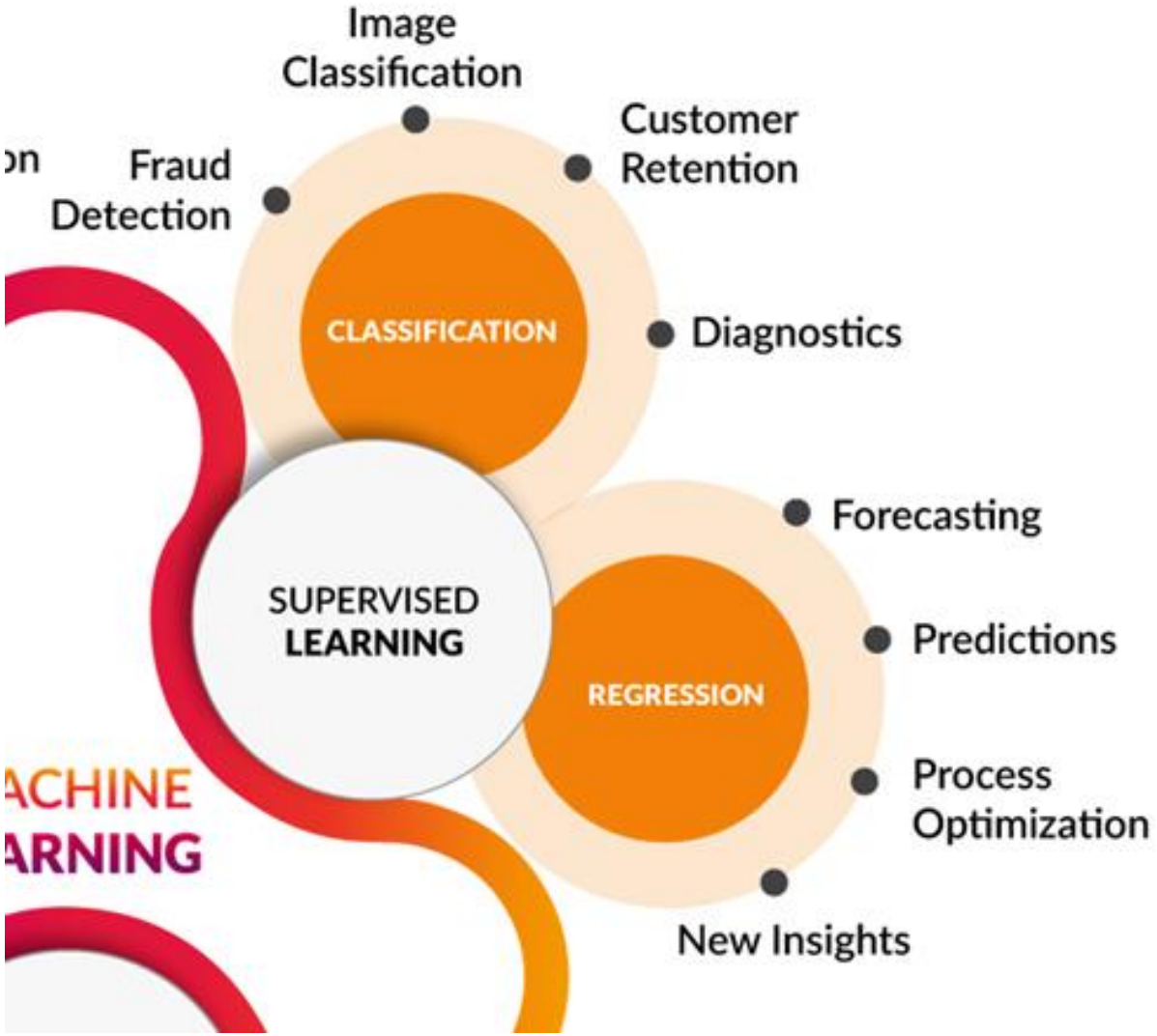
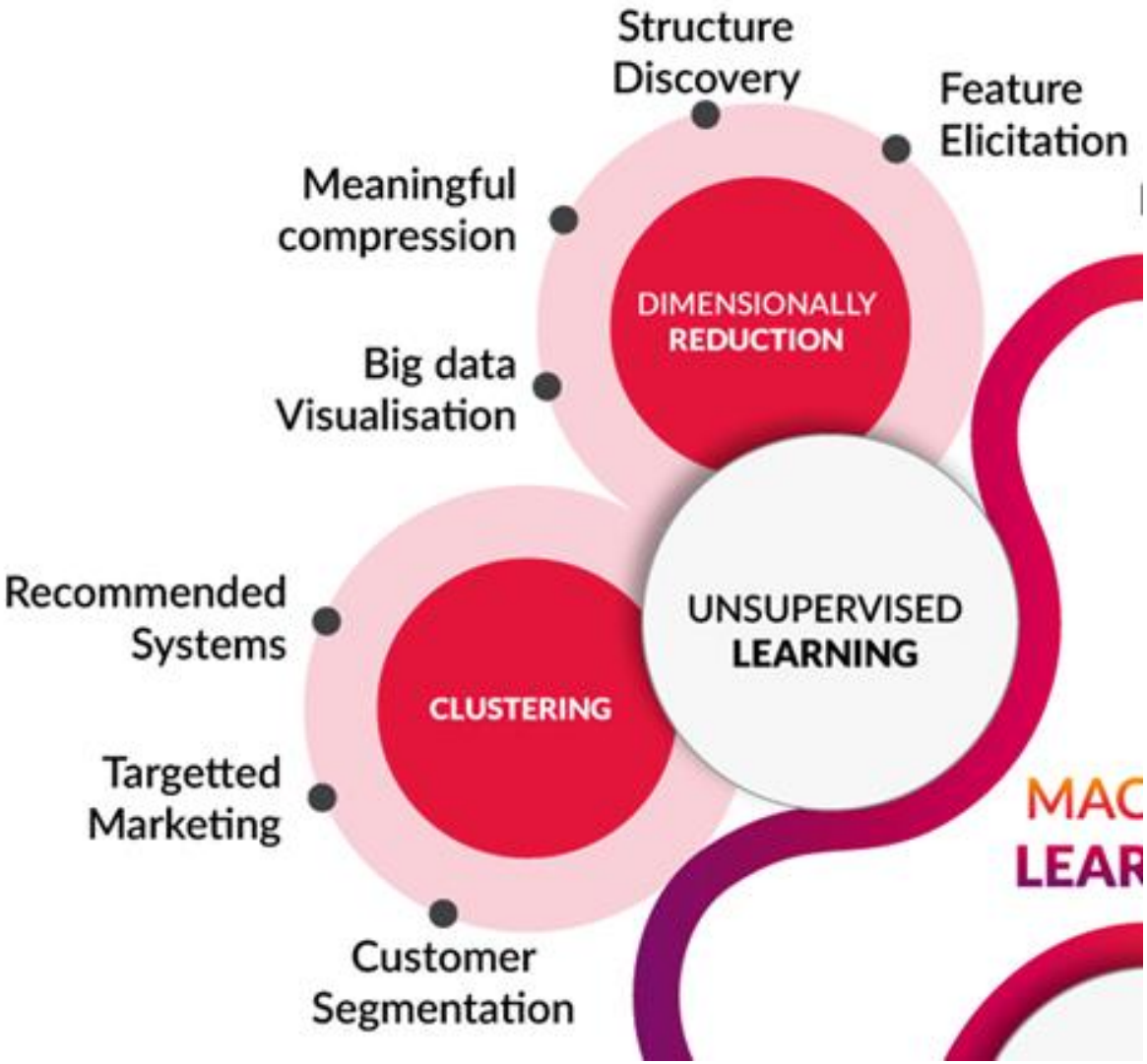
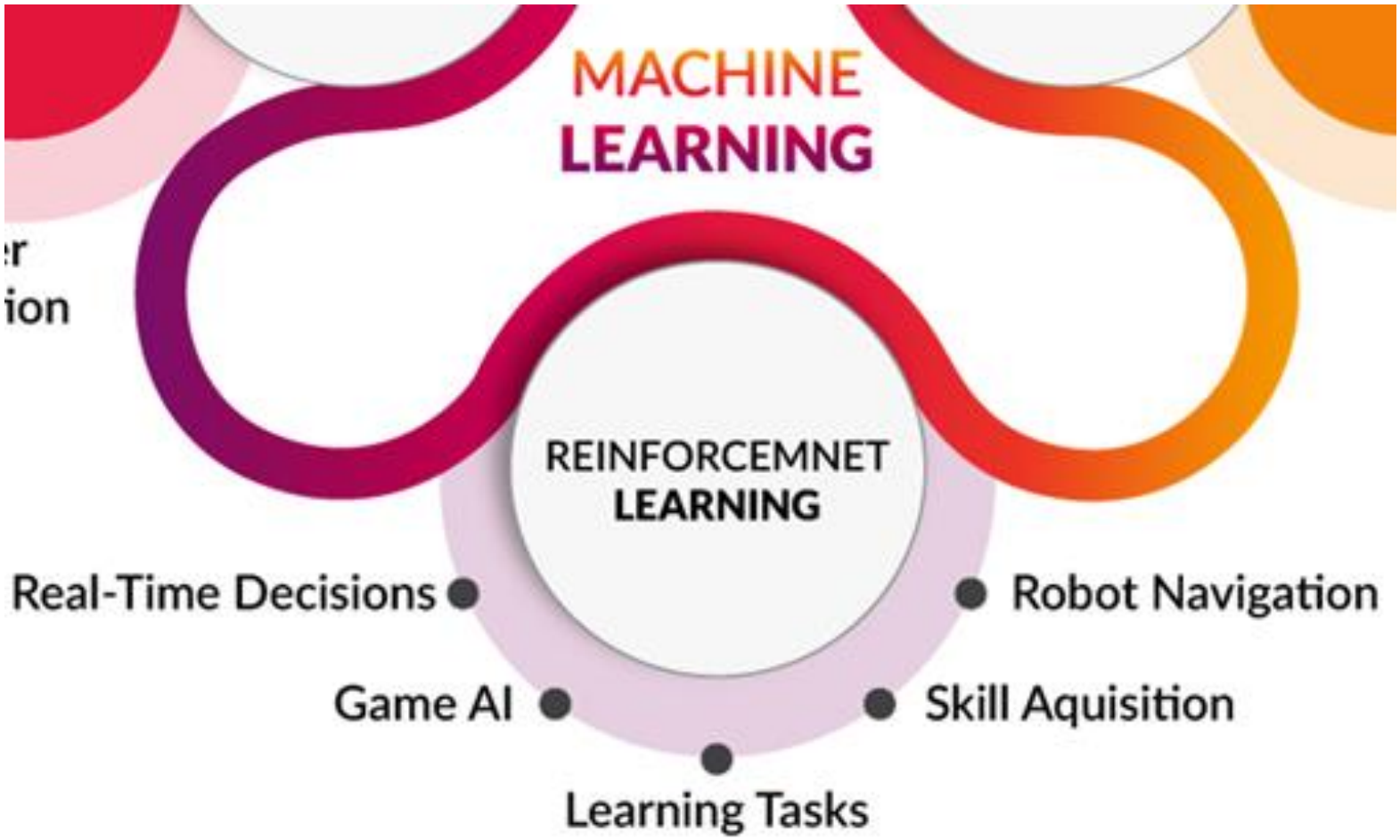


Image
Classification
Customer
Retention
Fraud
Detection
CLASSIFICATION
Diagnostics
Forecasting
SUPERVISED
LEARNING
REGRESSION
Predictions
Process
Optimization
New Insights

ML taxonomy


Structure Discovery
Feature Elicitation
Meaningful compression
DIMENSIONALLY REDUCTION
Big data Visualisation
Recommended Systems
CLUSTERING
UNSUPERVISED LEARNING
Targetted Marketing
Customer Segmentation
MAC
LEAR

ML taxonomy


MACHINE
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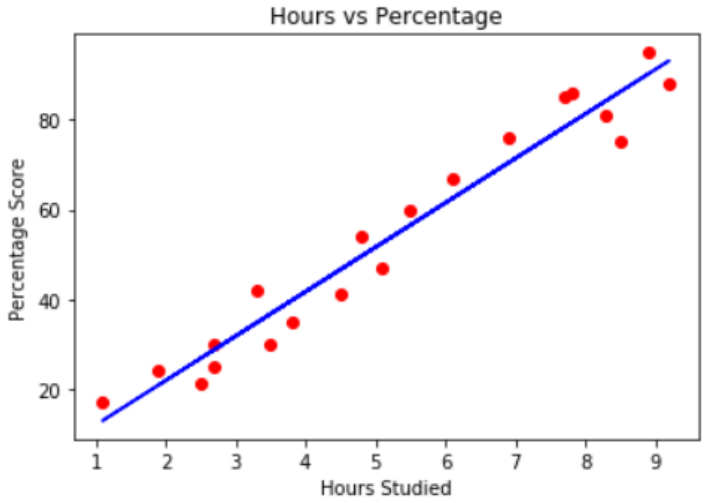
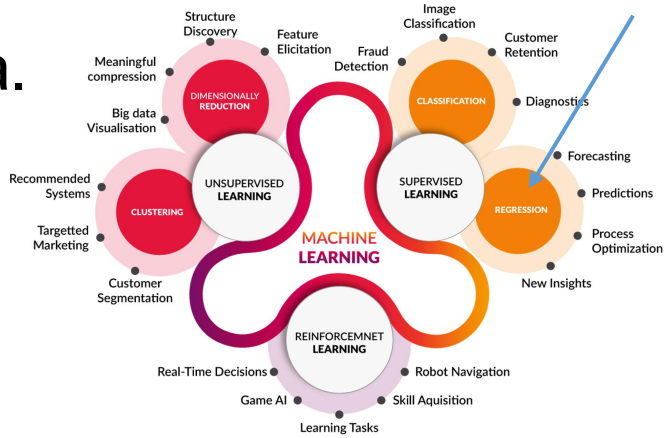
REINFORCEMNET
LEARNING
Real-Time Decisions
Robot Navigation
Game AI
Skill Aquisition
Learning Tasks

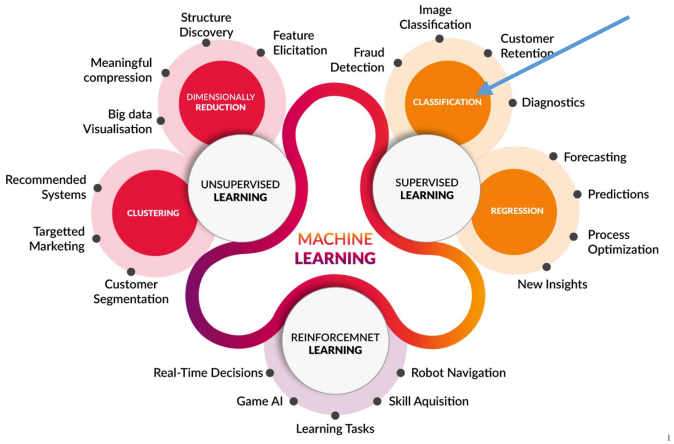
Regression



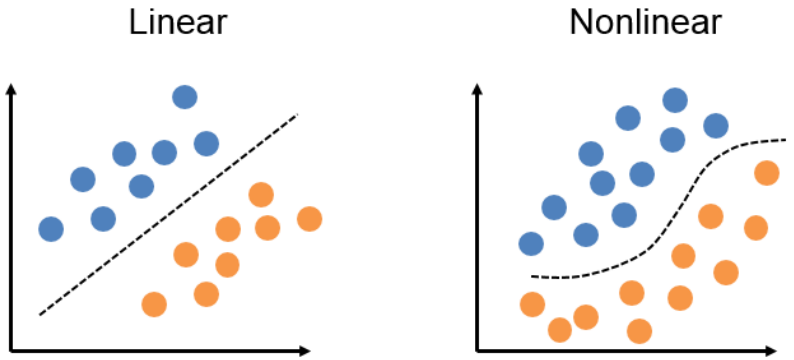
- It predicts **continuous** valued **output**.
- Compute the probabilistic relationship between *variables* for the purposes of *forecasting* or *prediction*.
- The Regression analysis is the statistical model which is used to predict the numeric data instead of labels.
  - That regression is the problem of predicting a continuous quantity output for an example
- It can also identify trends based on the available data or historic data.
- Example: predicting a person's income from their age, education, etc...



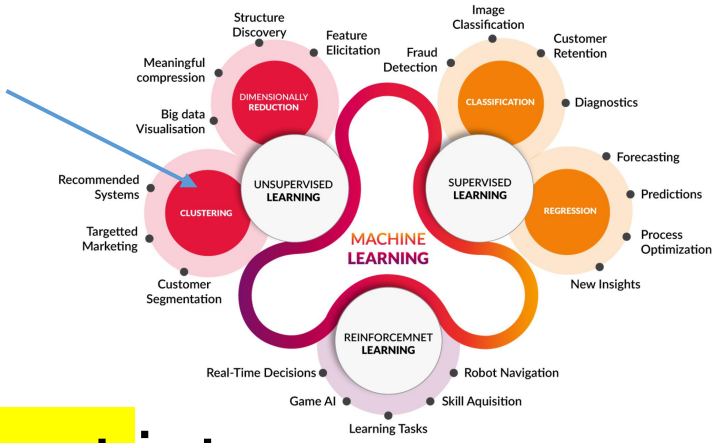
Classification



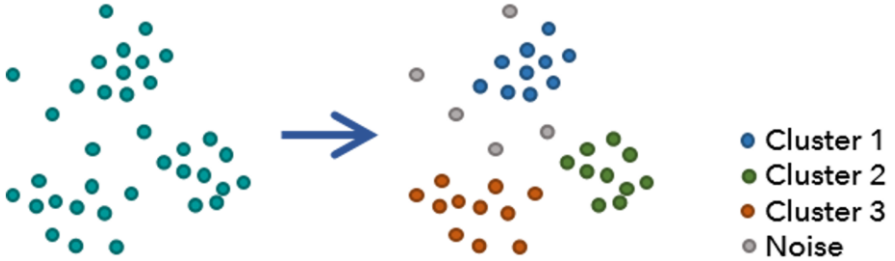
- It predicts discrete number of values processing the inputs
- In classification the data is categorized under different labels according to some parameters and then the labels are predicted for the data
- Classifying emails as either spam or not spam is example of classification problem
- Ex.: 2D input class.



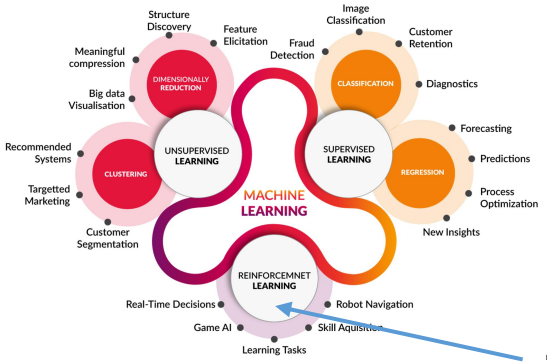
Clustering



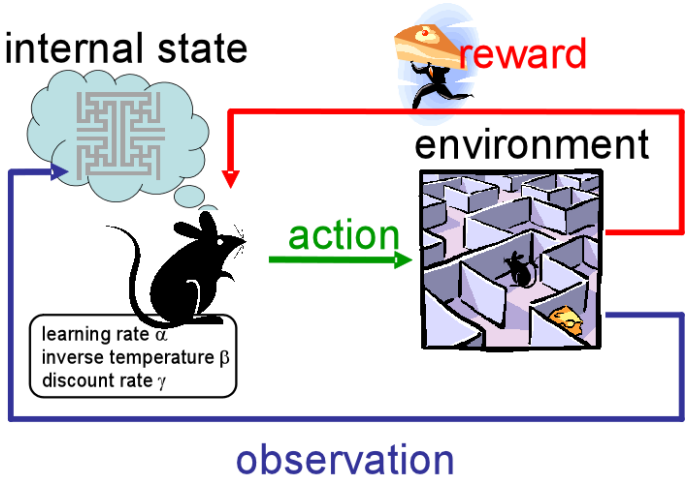
- the task of partitioning the dataset into groups, called clusters of similar items
- The goal is to split up the data in such a way that points within single cluster are very similar and points in different clusters are different
- It determines grouping among unlabeled data
- Ex.: 2D points



Reinforcement Learning



- Reinforcement learning models use opposite dynamics such as rewards and punishment to "reinforce" different types of knowledge.
- This type of learning technique is becoming really popular in modern AI solutions.

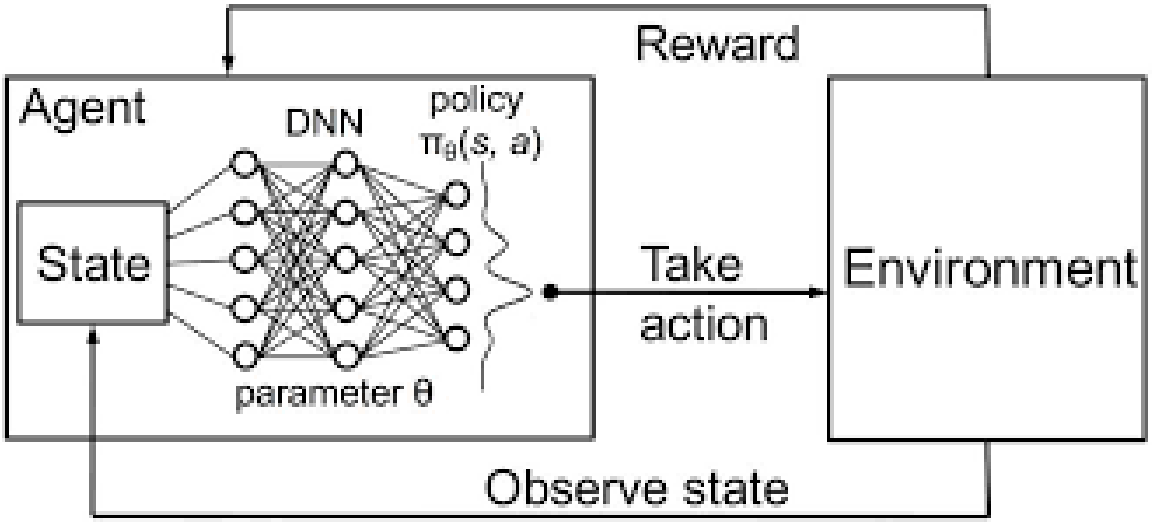


For example, the abilty to develop behaviors/patterns such as:

- Random walk
- Go as straight as possible
- Spiral/whorl

Reinforcement Learning (II)

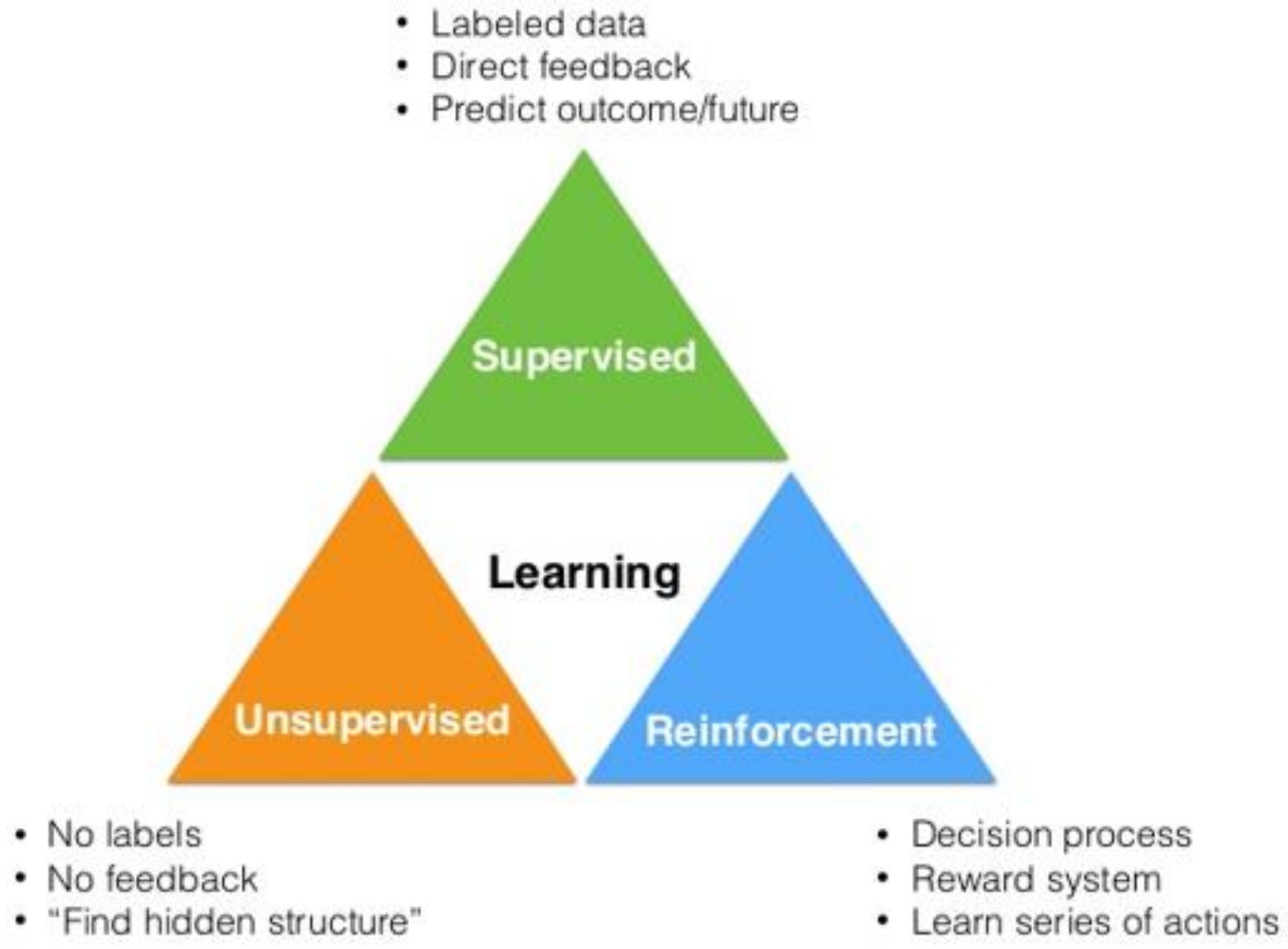
- Goal: get as much reward as possible!



Types of Learning VS labels

- **Supervised** (inductive)
  - Training data includes desired outputs (labels)
- **Unsupervised**
  - Training data does not include desired outputs
- **Semi-supervised**
  - Training data includes a few desired outputs
- **Reinforcement**
  - Rewards from sequence of actions

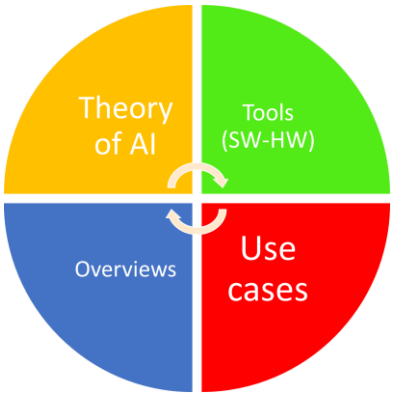
Types of Learning: another point of view



THEORY

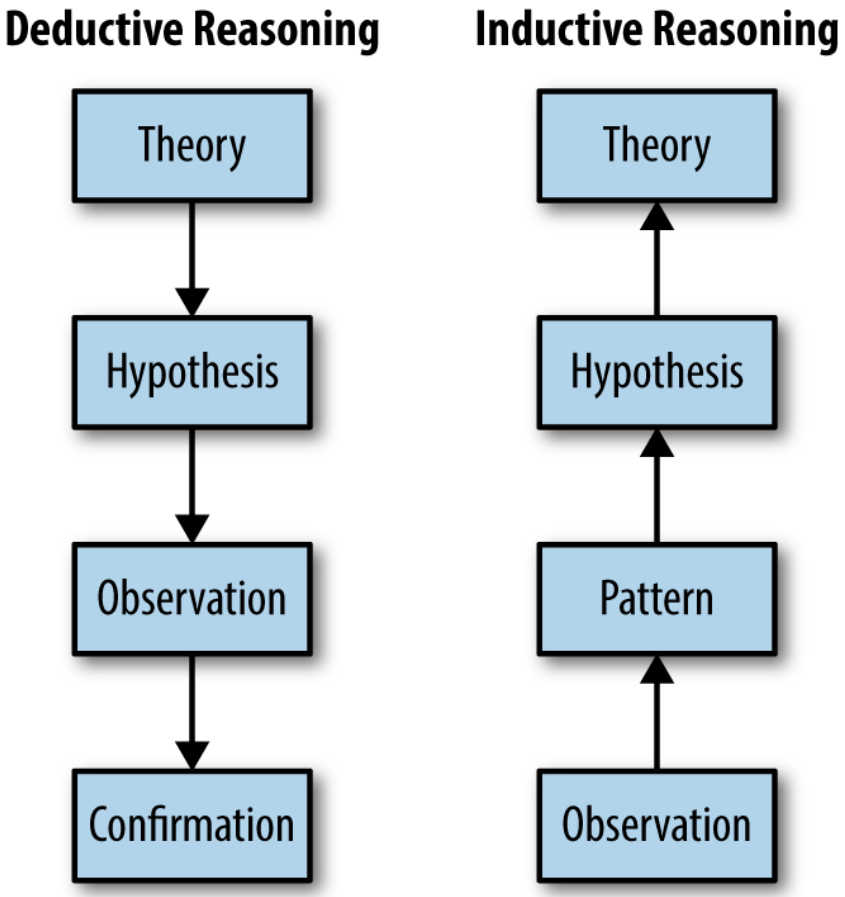
Deductive and Inductive learning

Learning from data or appling rules?

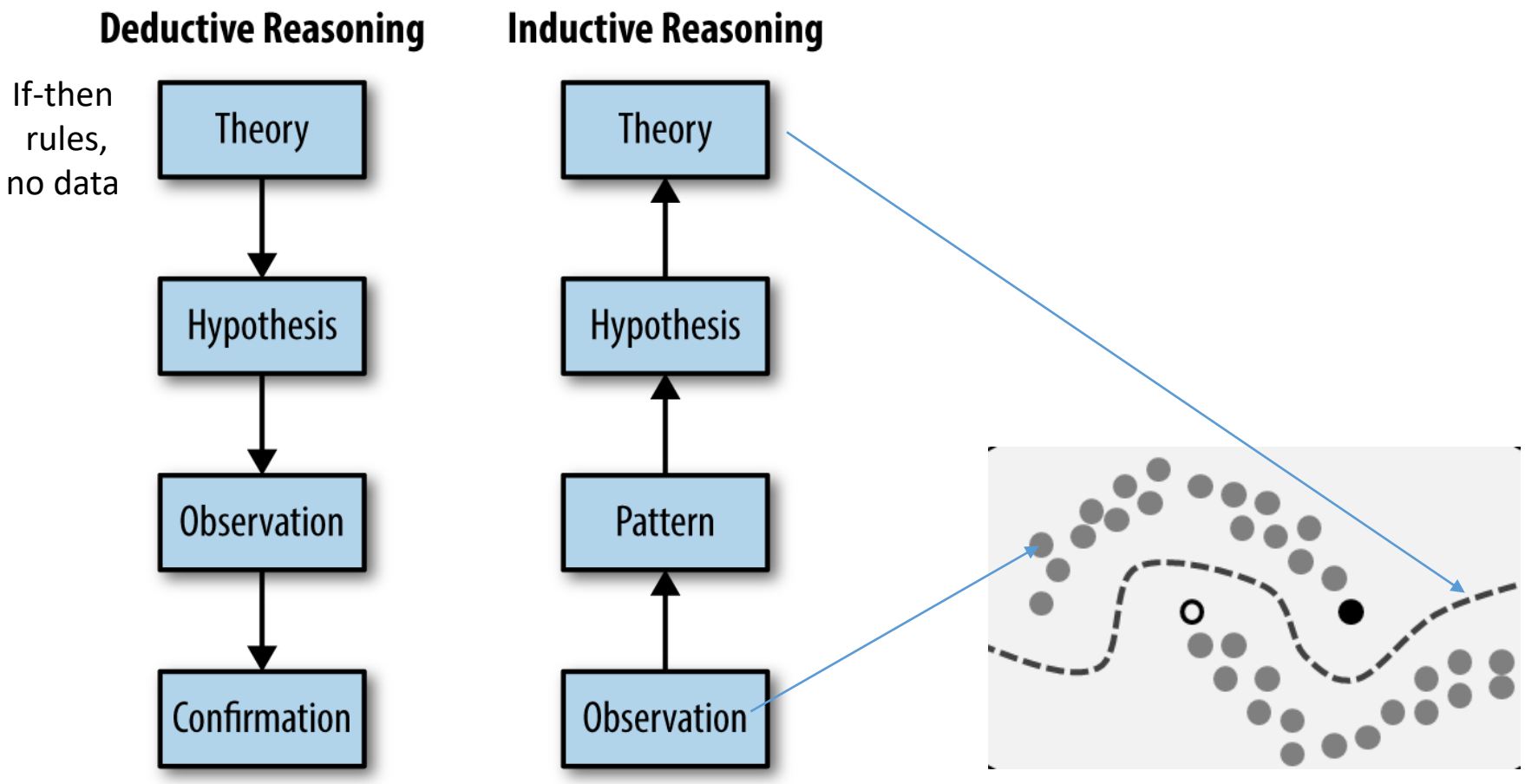


Deductive VS Inductive

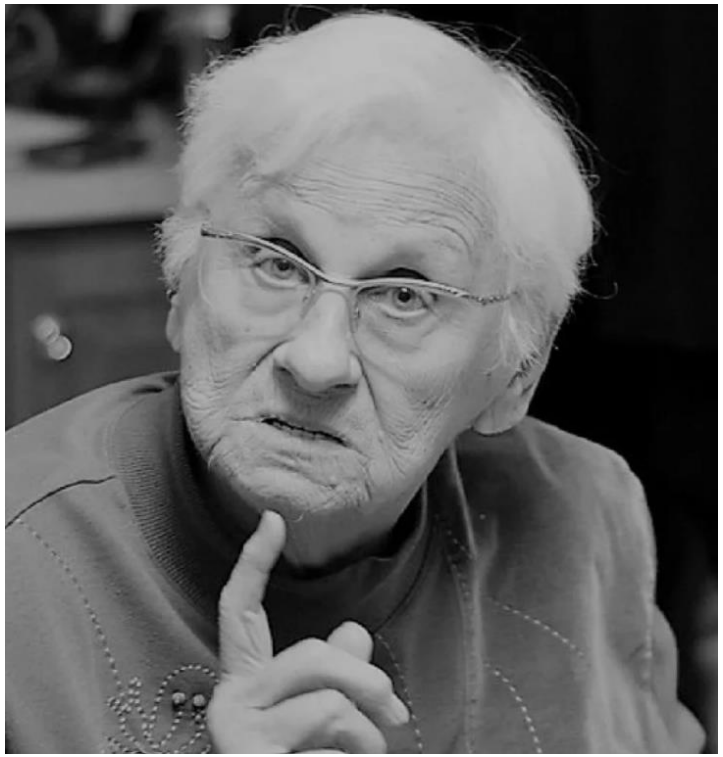
Example:
If-then rules,
no data



Deductive VS Inductive



Deductive learning



Let's use a mnemonic…
your grandmother is giving you the rules to choose a good fiancé

(if you agree…) you are inheriting knowledge from her previous experience and to apply them to choose the new partner

Then… You can also adapt the rules to modern time.

Deductive learning is a type of AI technique starting with a set of rules and process new decisions on new data
Then… inferring new rules that are more efficient in the context to be applied

Inductive learning

James Dean, Rebel Without a Cause (1955)

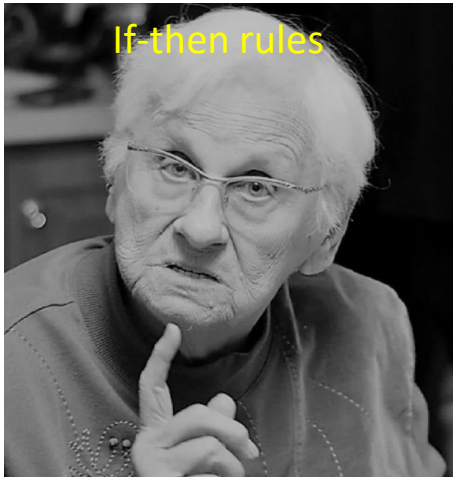
Let's use a mnemonic… you don't want rules and you want gather your knowledge by experience

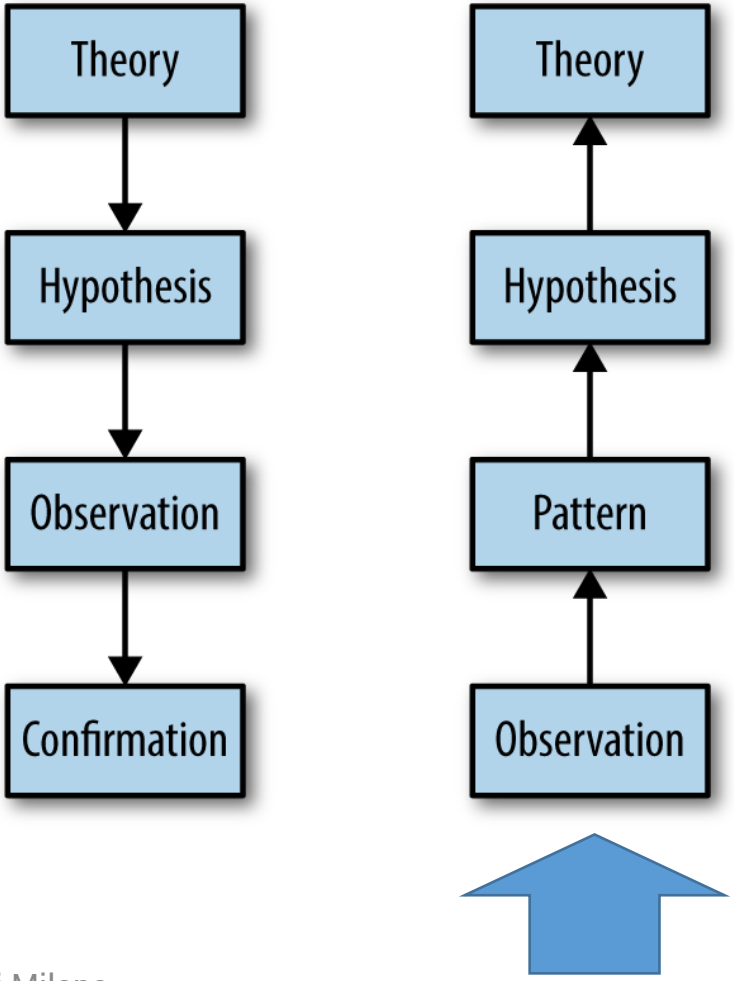
Last 10 times I entered Milano's highway @17:30 I got stuck in a jam!

→ NEW GENERAL RULE: Avoid departure in heavy traffic time

Inductive learning is based on inferring a general rule from datasets of input-output pairs

Deductive VS Inductive



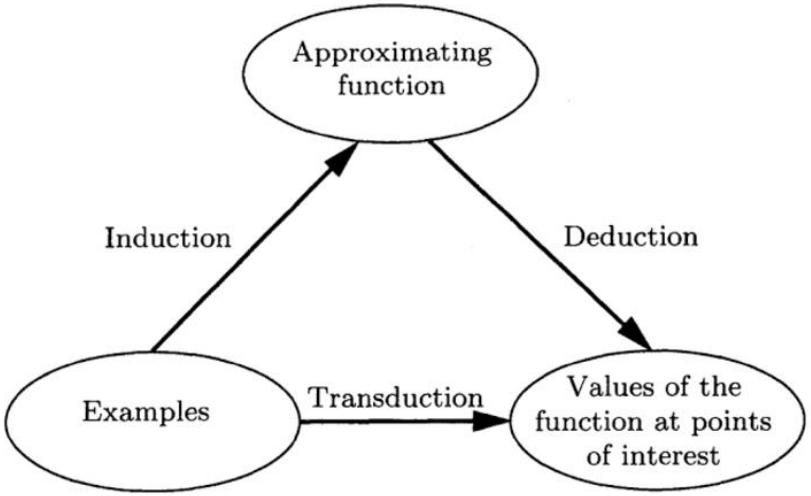


No previous knowledge, just data

THE MAJORITY OF AI METHODS

Transduction…

- ***Induction**, deriving the function from the given data.*
- ***Deduction**, deriving the values of the given function for points of interest.*
- ***Transduction**, deriving the values of the unknown function for points of interest from the given data.*



The Nature of Statistical Learning Theory

Many natural language processing (NLP) tasks can be viewed as transduction problems since the model converts one string into another.

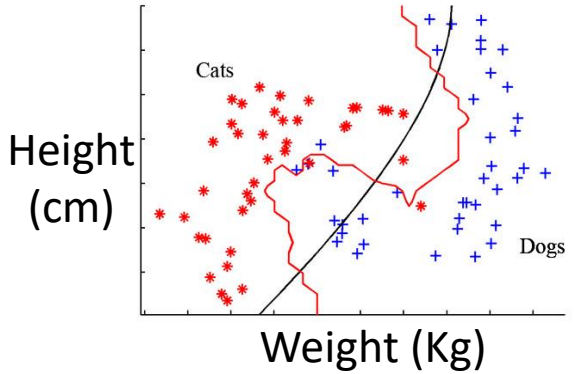
Inductive Learning

- Given examples of a function (X, F(X))
  - X=0,2 --> Y=32;
    X=0,5 --> Y=52;
    ….
    (1-Dimensional case)
  -  → Y= 1;  → Y= 1;  → Y= 2;

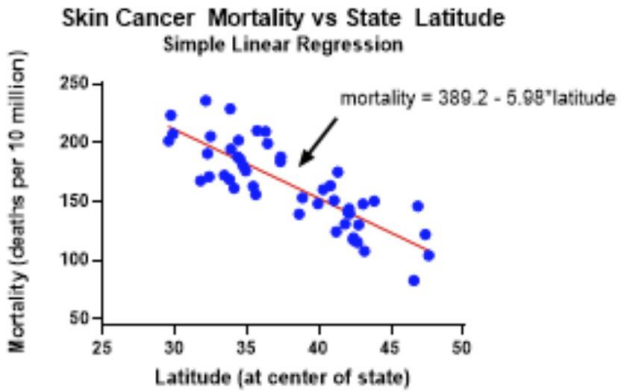
    (N-Dimensional case)

Inductive Learning (2)

- Create a prediction function F(X) for new examples X
  - Discrete F(X):
    - Classification out=F(X) is an *integer*



  - Continuous F(X):
    - Regression
      - Example:
        F(X) = Probability(X)
        Probability estimation



Inductive Learning: Advantages

- Alleviate knowledge acquisition Bottleneck (no rules, no equations, just data)
  - Does not require knowledge engineers
  - Scalable in constructing knowledge base
- Adaptive
  - Adaptive to the changing conditions
  - Easy in migrating to new domains

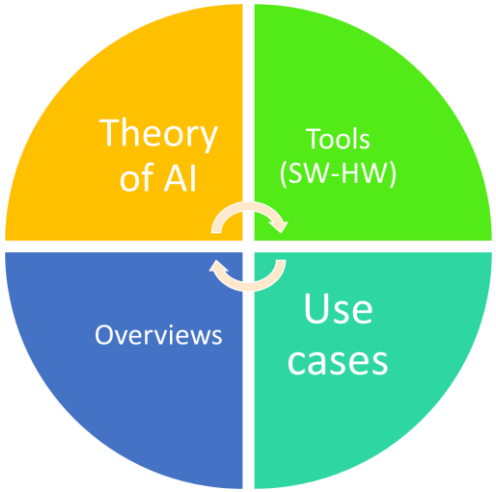
Inductive Learning: Generalization

- The obtained (trained) model can generalize the capability to solve a problem in the specific application to more general cases
- IF (there are a lot of IFs)
  - the dataset is good and complete,
  - the learning method and the model are enough powerful
  - etc..




Overview

Intelligent sensors,
and environmental control



Intelligent sensors

- Heterogeneous multi-sensor systems.
- Sensor data analysis.
- Diagnosis.
- Fault tolerance.
- Self-calibration.
- Adaptivity.
- Management.

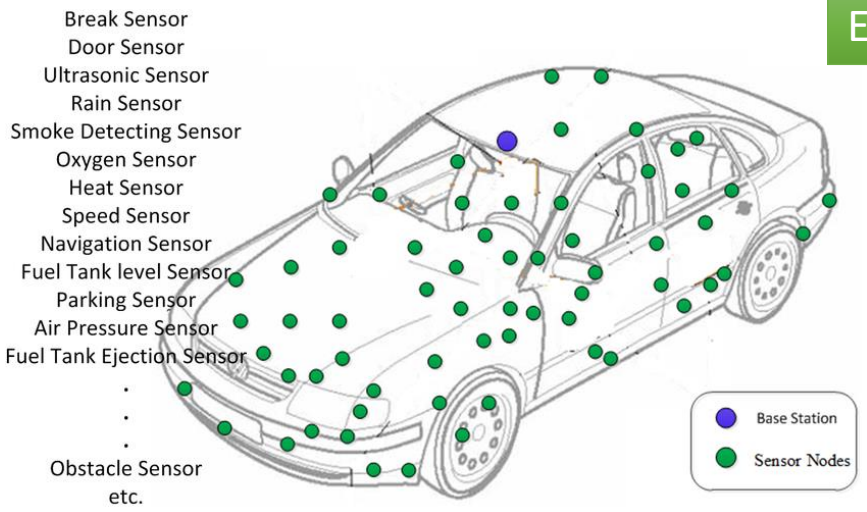
Example

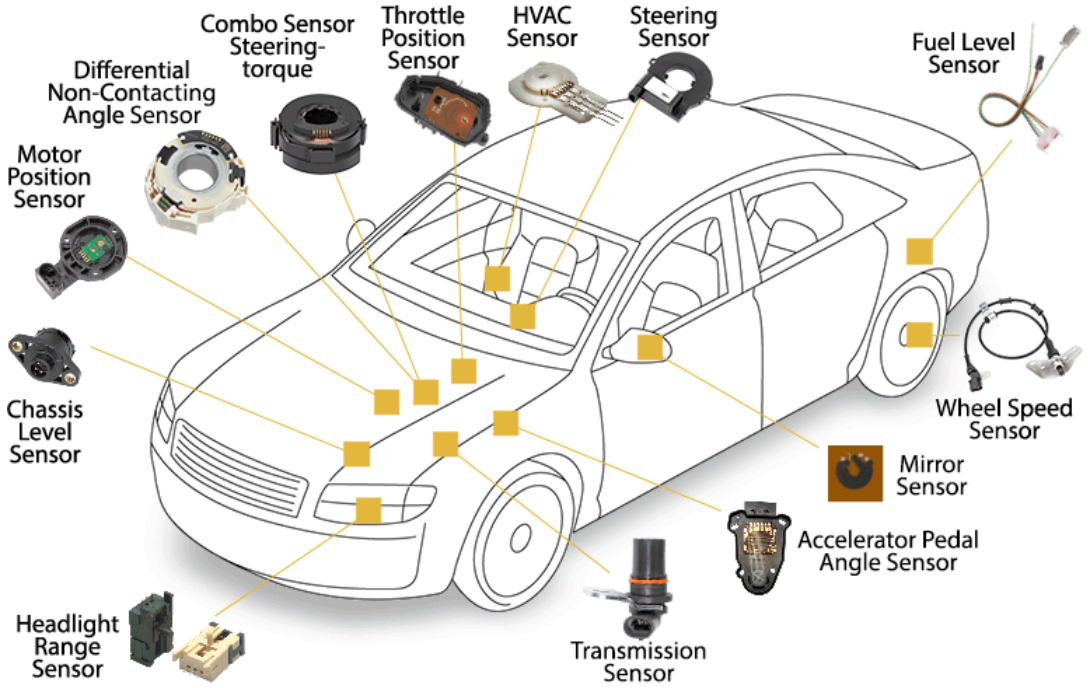
Nest Labs: co-founded Tony Fadell and Matt Rogers in 2010 (former Apple engineers); the flagship product was the Nest Learning Thermostat (from 2011).
Google acquired Nest Labs for 3.2 billion US$ in January 2014 (with 280 employees).

Sensor networks

- Structure
- Functions
- Adaptivity
- Management
- Distributed data analysis
- Fault tolerance
- Diagnosis

Example





Instrumentation and Measurements

- Acquisition and processing of sensor measurement in advanced adaptive infrastructures
- Multi-sensorial data fusion
- AI-based Virtual Sensors
  - AI provides feasible and economical alternatives to costly or impractical physical measurement instrument.
    A virtual sensing system uses information available from other measurements and process parameters to calculate an estimate of the quantity of interest.

Environmental monitoring

Applications of intelligent system for complex system monitoring and environmental monitoring.

Main points

- Prepare your toolboxes!
  (Matlab, Colab, and the other resources)
- In this field, knowledge **interiorization** is needed to create **skills**
- Taxonomy of machine learning methods
- Focus on
  - Regression
  - Classification
  - Clustering
  - Deductive and inductive learning
- Overview of AI applied to sensors
  - Intelligent sensors
  - Networks of sensors
  - Advanced instrumentation and virtual sensors