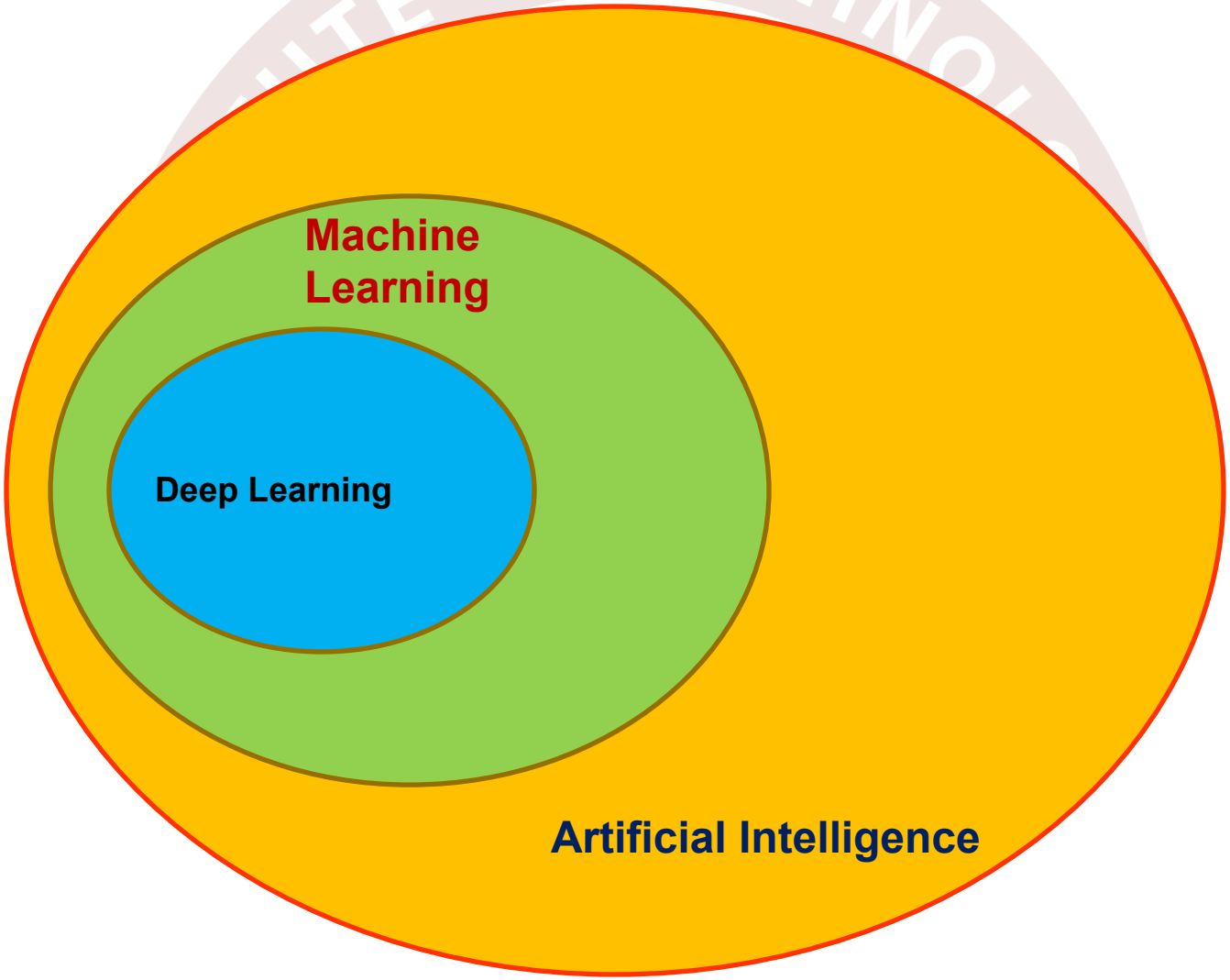
Machine Learning for Engineering and Science Applications

Overview of Machine Learning

Some common terms

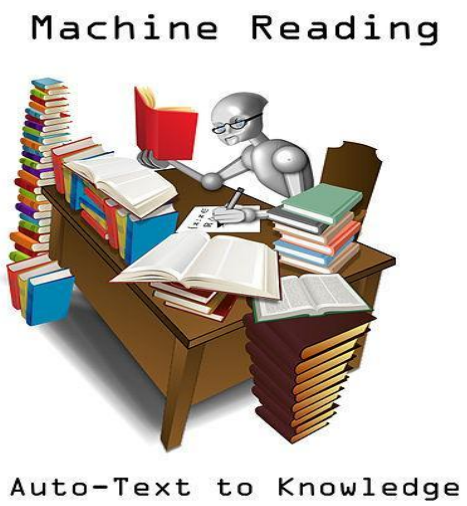
- Artificial Intelligence – Any method that tries to replicate the *results* of some aspect of human cognition
- Machine Learning – Programs that perform better with experience.
- Artificial Neural Networks (ANN) – A Machine Learning algorithm
- Deep Learning – A type of ANN
- Big Data – Using data to find unobvious patterns

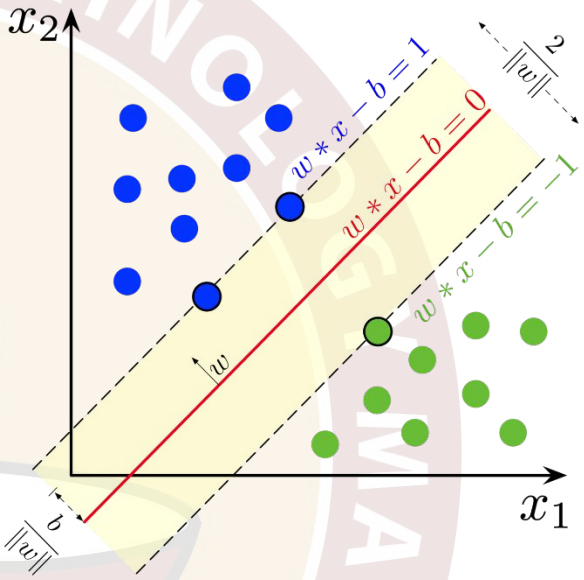
The AI Venn diagram



Adapted from *Deep Learning*, Goodfellow et al (2016)

What is Machine Learning?





- Simple Definition -- Using Data to answer questions
- Study of computer algorithms
  - that improve automatically
  - through experience.
- Formally, 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*.

https://upload.wikimedia.org/wikipedia/commons/thumb/6/6a/Maching_Reading_Robot_Auto-Text_to_Knowledge.jpg/463px-Maching_Reading_Robot_Auto-Text_to_Knowledge.jpg

Yufeng Guo -- https://www.youtube.com/watch?v=HcqpanDadyQ

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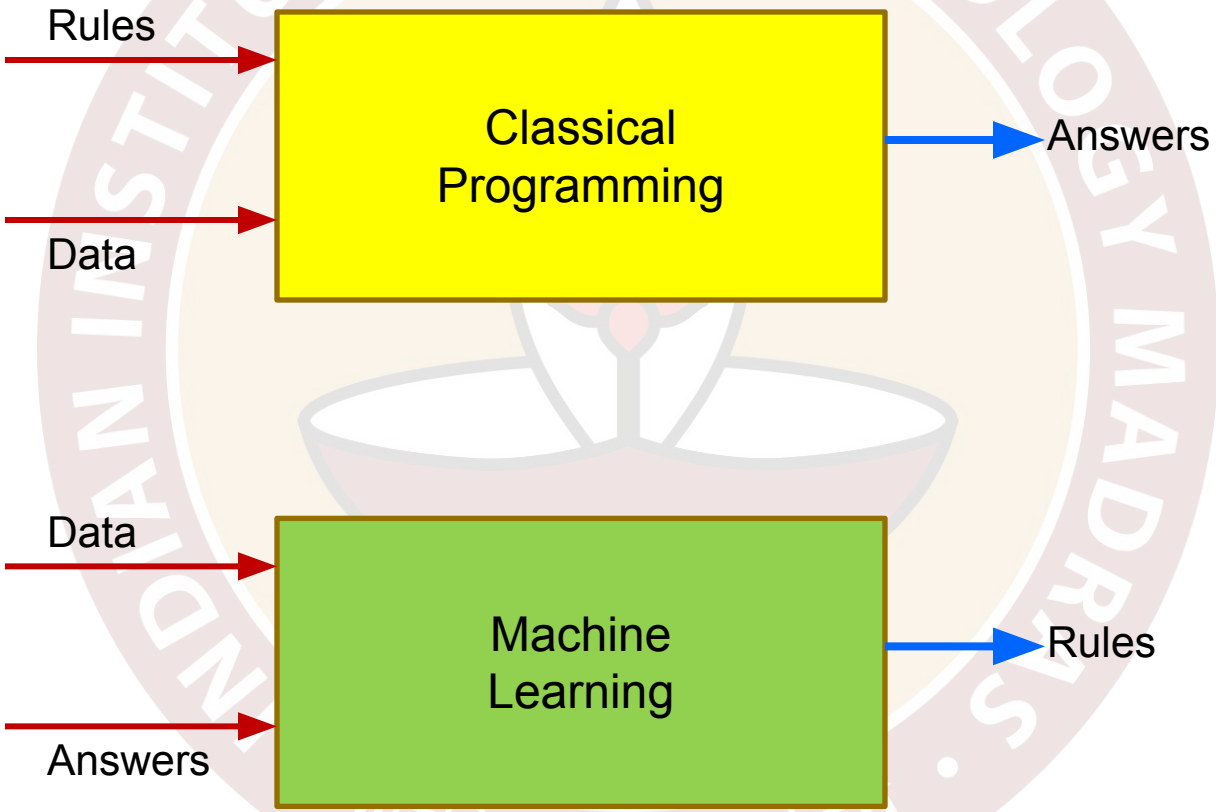
The Machine Learning Paradigm



Idea adapted from Pedro Domingo (multiple sources) and Francois Chollet (Deep Learning with Python)

When is Machine Learning useful?

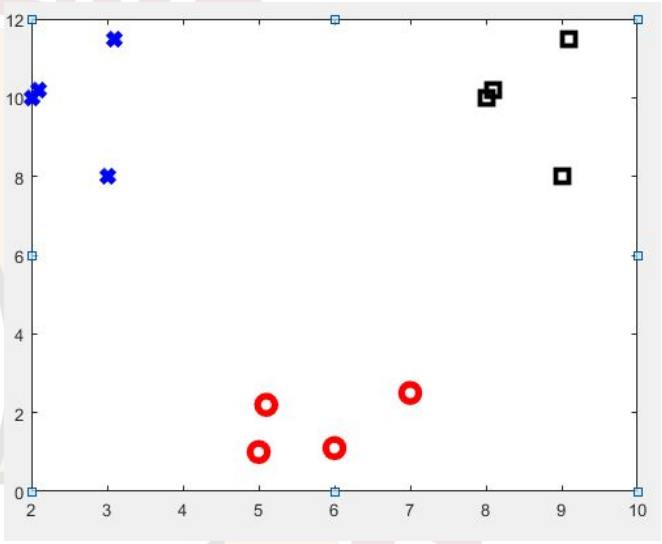
- When experts are unable to explain their expertise
  - Image recognition
  - Speech recognition
  - Driving a car
- When Human expertise does not exist
  - Hazardous environments -- Navigating on Mars
- Solution needs to be adapted to particular cases
  - User biometrics
  - Patient specific treatments

A fundamental "trick" in most of ML

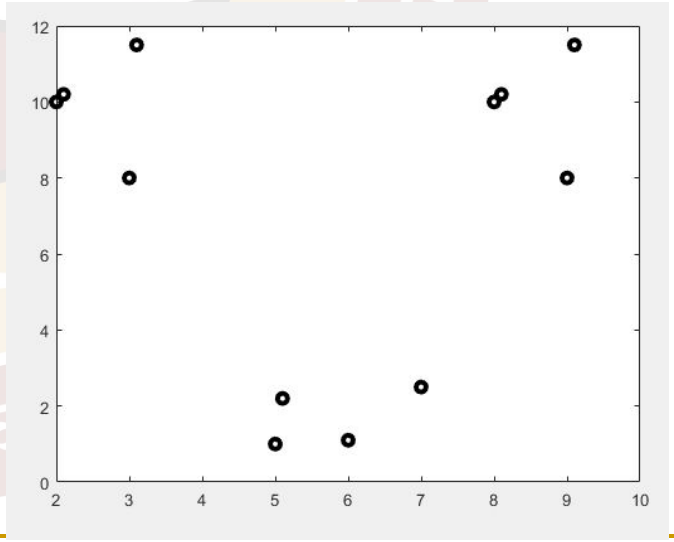
- All problems are data, all solutions are functions/maps
- Cognitive tasks -- Humans get sensory inputs as qualia
  - We must convert these qualitative inputs into numbers – Input Vectors
  - Similarly, outputs that humans give must also be converted into numbers – Output/Target vectors
- Determining appropriate inputs and outputs for a machine learning task is an essential part of the process
- Often the "Learning Task" is learning the mapping from input to output.

Types of learning approaches

- Supervised Learning
  - Data labeled by human experts
  - Labeling images
  - Speech recognition
  - OCR



- Unsupervised Learning
  - Unlabeled data
  - Grouping customers
  - Detecting new diseases
  - Anomaly detection



Other types of learning approaches

- Generative approaches
  - Creating new data that is “like” given data
  - Generally included in unsupervised learning
- Semi-supervised learning
  - Small amount of labeled data available along with unlabeled data
- Self-supervised learning
  - Implicit labels are extracted from data using heuristics
- Reinforcement learning
  - Actions are chosen based on rewards. Example : Chess, Games, etc
  - Feedback is far removed temporally from action

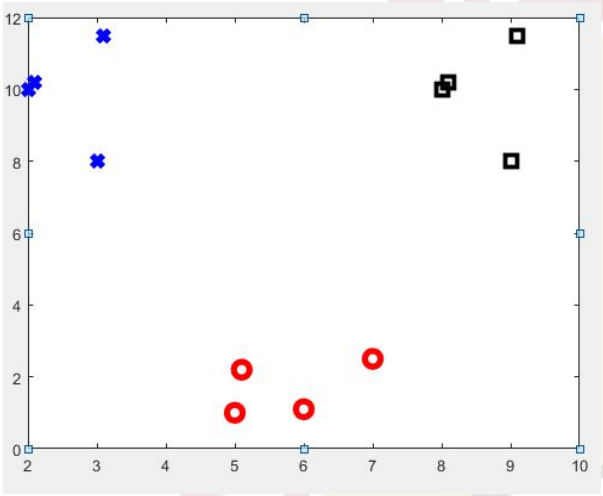
The distinction between the various types of learning is often blurred

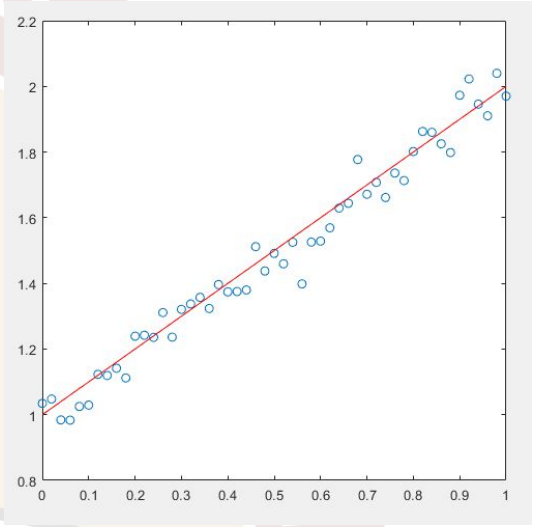
Seven Steps in Machine Learning

1. Gathering Data
   - Deciding what “data” means is part of the problem
2. Preparing Data
   - Ensuring that there is no bias
3. Choosing a Model/Algorithm
   - Examples – Random Forest, ANNs, Hidden Markov Models,etc
4. Training
   - Using data to determine model parameters
5. Evaluation – How well did we do?
6. Hyperparameter Tuning
7. Prediction

Yufeng Guo -- https://www.youtube.com/watch?v=nKW8Ndu7Mjw

Two problems in Supervised Learning





Classification	Regression
Split it	Fit it
Discrete or Categorical data.	Real number data
Has category associated	Has associated number
Example : Tumour classification	Example : Prediction of stock market

Mathematical ideas we will be using in this course

- Linear Algebra
  - Machine Learning involves mapping
    - From vectors to vectors
    - That is, matrix based transformations – Linear Algebra
- Probability
  - Data and results have uncertainty built into them
  - Conditional probability is a very important component of ML
- Optimization
  - For a given set of data what is the “best” model?
  - Many ML models finally reduce to solving some optimization problem