Machine Learning Overview

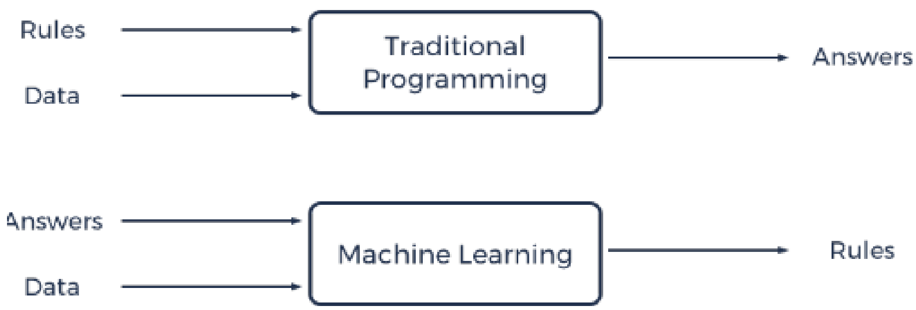

Figure 1: Example of how machine learning works compared to programming

Artificial Intelligence

Intelligence: anything that can think rationally: making decisions, predictions and detecting patterns.

- **Search and Optimization**: Determine the complete solution space to a problem, then enumerate over the possibilities that can occur to find the values that perform the best.
- **Logic**: Propositional logic and first-order logic can model a problem. When presented with a new problem using the same logic statement structures, the developed model can then determine if the problem statements aligns with the original model.
- **Machine Learning**: ML uses data, and sometimes an answer to a question, to determine the underlying rules that define a system.

Machine Learning

Machine learning is the learning of a model that can accurately represent the reality it models. Machine learning consists of three primary types:

- **Supervised Learning**: supervised learning determines a model that can take an input set of features and predict a label for these features. We do so by training the model given a set of inputs with predetermined labels and learning the rules that result in that label. If the label to predict is a continuous value, then the problem is a *regression* problem. If the label to predict is a discrete value then the problem is a *classification* problem.

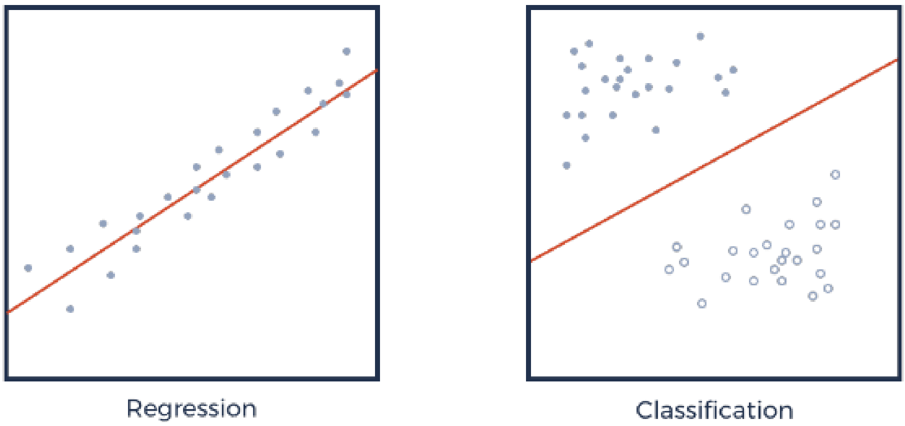

Figure 2: Regression VS Classification

- **Unsupervised Learning**: Unsupervised learning does not use predetermined labels and instead detects pattern in data. Pattern include finding similarities between some data points and differences with others. A simple example of unsupervised learning is clustering.

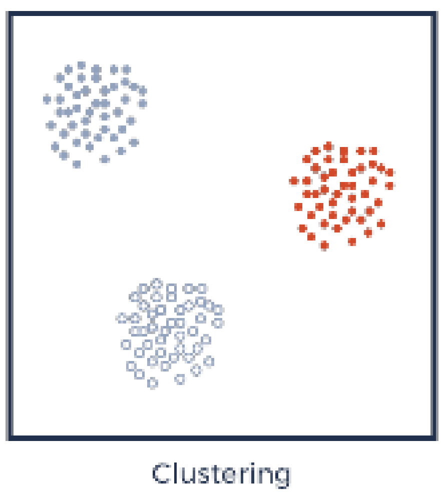

Figure 3: Clustering example

- **Reinforcement Learning**: Reinforcement learning trains a model to make decisions based on a reward or punishment. Reinforcement learning algorithms model as much as possible of the real world scenario and run a large number of simulations to account for variations to learn the appropriate decisions.

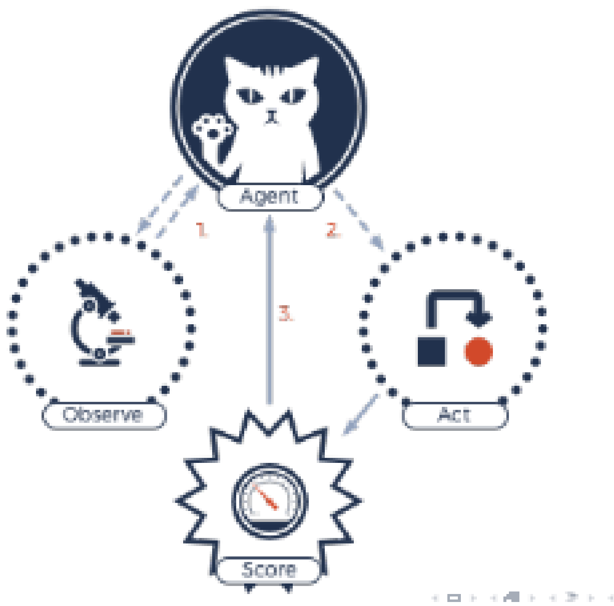

Figure 4: Reinforcement example

Other popular types/subsets

- **Semi-supervised learning**: When we have a small subset of data with labels and the remaining subset unlabeled, and train a model to predict labels.
- **Multi-Label Learning**: Supervised learning where we have more than one target label to predict. Ex: labeling all the objects in an image
- **Multi-View or Multi-Model Learning**: Data representing an entity can come in different formats each presenting a potentially different perspective. Ex: brain image of a patient and genetic data of the patient can both represent the patient.
- **Multi-Instance Learning**: Data contain pieces called instances, that make up the whole data record. Ex: image made up of patches, each containing a desired item to identify
- **Zero Shot Learning**: Supervised learning where the model can classify an item as none of the classes that it trained on. Ex: training on images of cats and dogs and being able to tell a horse is neither of those.
- **Transfer Learning**: Transfer learning is the study of problems where the distribution of training data and testing data are different. Ex: training a translational model on 2 languages but using it on a third language.

- **Active Learning**: Active learning is where a learning algorithm is able to interact with a user to obtain desired outputs for new data. In traditional engineering fields, it is also called experimental design.

Data Representations

In AI, we use different data representation for real world objects.

We often summarize our data to have a more concise representation. This is done to minimize redundancy represented by two or more features.

Dimensionality reduction is the field that studies this data summarization. When representing data, each attribute of data is a *dimension* or *feature*. Dimensionality reduction reduces the number of dimensions in data to achieve certain learning goals such as minimizing information loss.

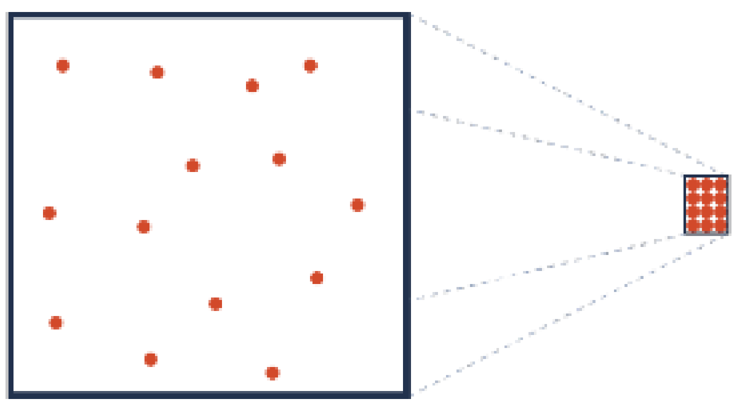

Figure 5: Dimensionality reduction visualization

Deep Learning

Deep Learning: a subset of machine learning that uses *deep neural networks* to solve machine learning problems.

A neural network (NN) is a graph of network made up of perceptrons or neurons organized in layers.

Each perception takes n inputs of data, combines them with allocated weights to each feature to create a weighted sum that gets passed to an *activation* function to produce an output.

Deep Neural Network: a network that has a large number of layers between the input and output. Layers between the input and output are *hidden layers*

Feed Forward Neural Network (FFNN)

A feed forward neural network is one where the flow of data between perceptrons does not create a cycle. Layers organize the structure of a neural network; perceptrons on the same layer are not connected to each other, receive inputs from a previous layer, and output to the next in a FFNN.

Convolution Neural Nets (CNN)

CNN works by encoding features into a lower dimension that is the input to a FFNN or neural network of another type.

Recurrent Neural Nets (RNN)

RNN can have cycles in the data flow between perceptrons. A popular example of RNN is Long-Short Term Memory Networks

Generative Adversarial Nets (GAN)

GAN works by creating two competing models; a *generator* or forger and a *discriminator* or detective. The end result is a model that can create fake data that is difficult to identify as fake and a model that can identify fakes.

Applications

- Computer Vision: use matrix/tensor to represent images
- Neural Language Processing: term frequency matrix to represent documents
- Bioinformatics
- Medical Image Computing