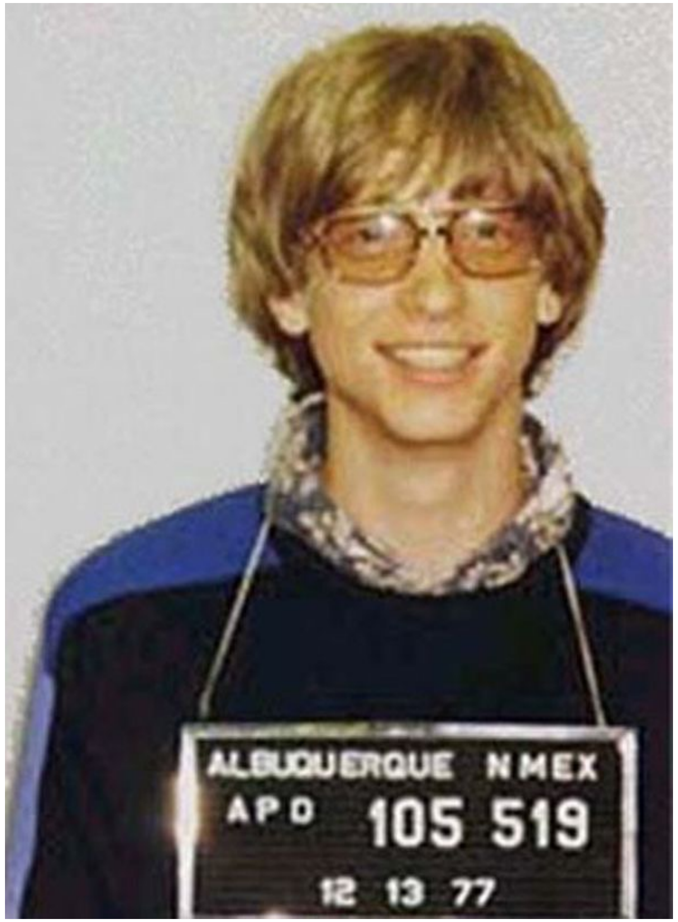
What is Machine Learning ?

Slides inspired by Sebastian Raschka STAT451 Intro to ML

Comments and Definitions

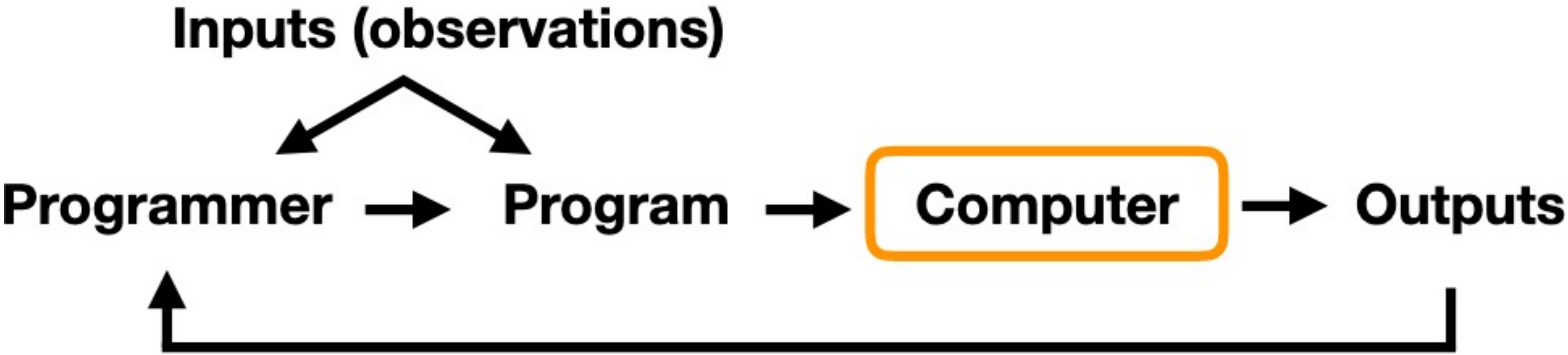
- "A breakthrough in machine learning would be worth ten Microsofts"
  —Bill Gates, Microsoft Co-founder



- Machine learning is the field of study that gives computers the ability to learn without being explicitly programmed”
  — Arthur L. Samuel, AI pioneer, 1959

The Traditional Programming Paradigm

Spam Filter with rules for example



In machine learning, the programmer doesn’t develop the filter, we let the computer figure it out.

The outputs are on **the left** here, so the computer has examples of labeled emails

- “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, Professor at Carnegie Mellon University

Example

- Task T : ?
- Performance Measure P : ?
- Training Experience E : ?

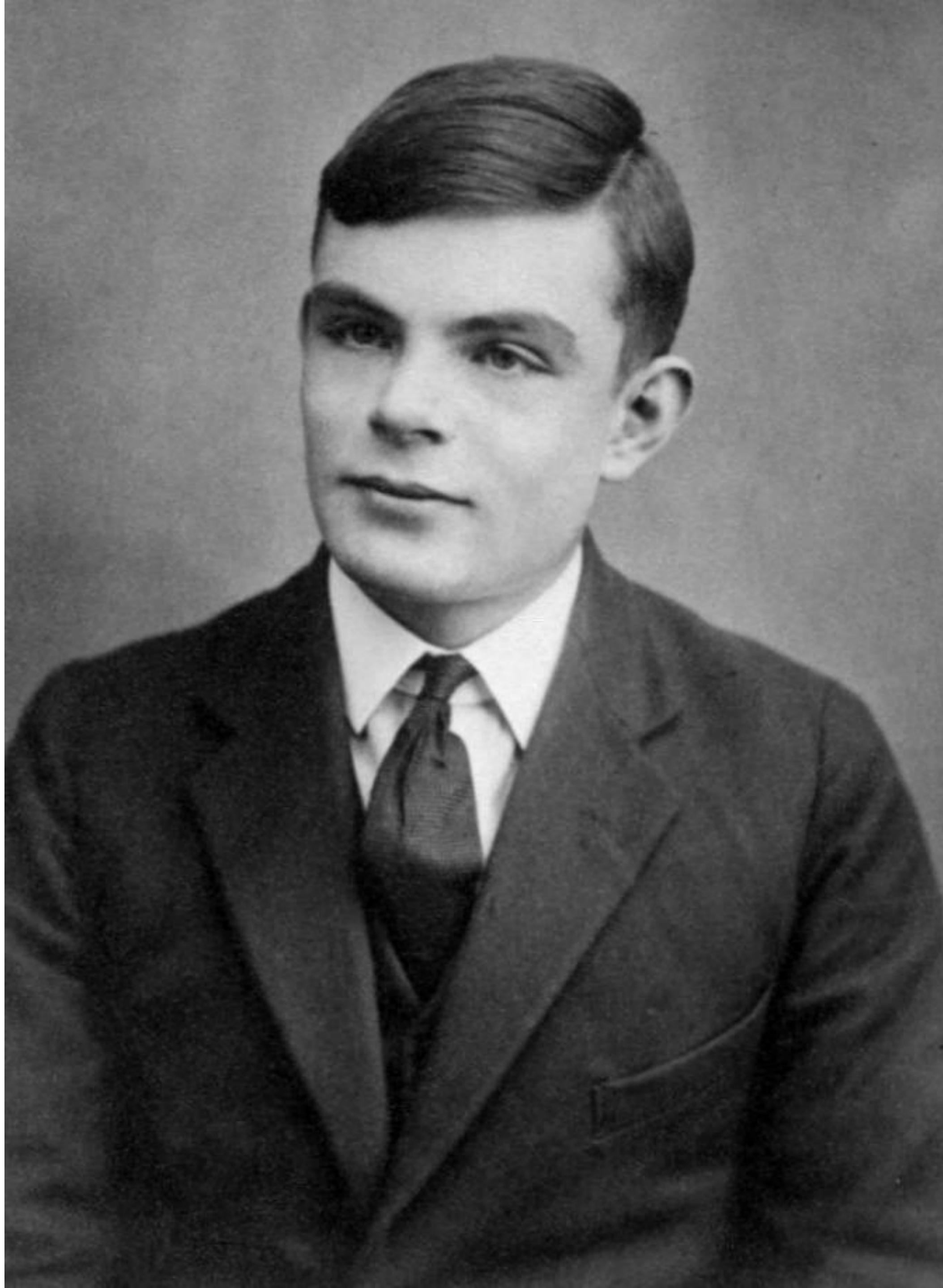
Handwriting Recognition Example:

MNIST Dataset
50K examples of
handwritten
digits, labeled

Alan Turing

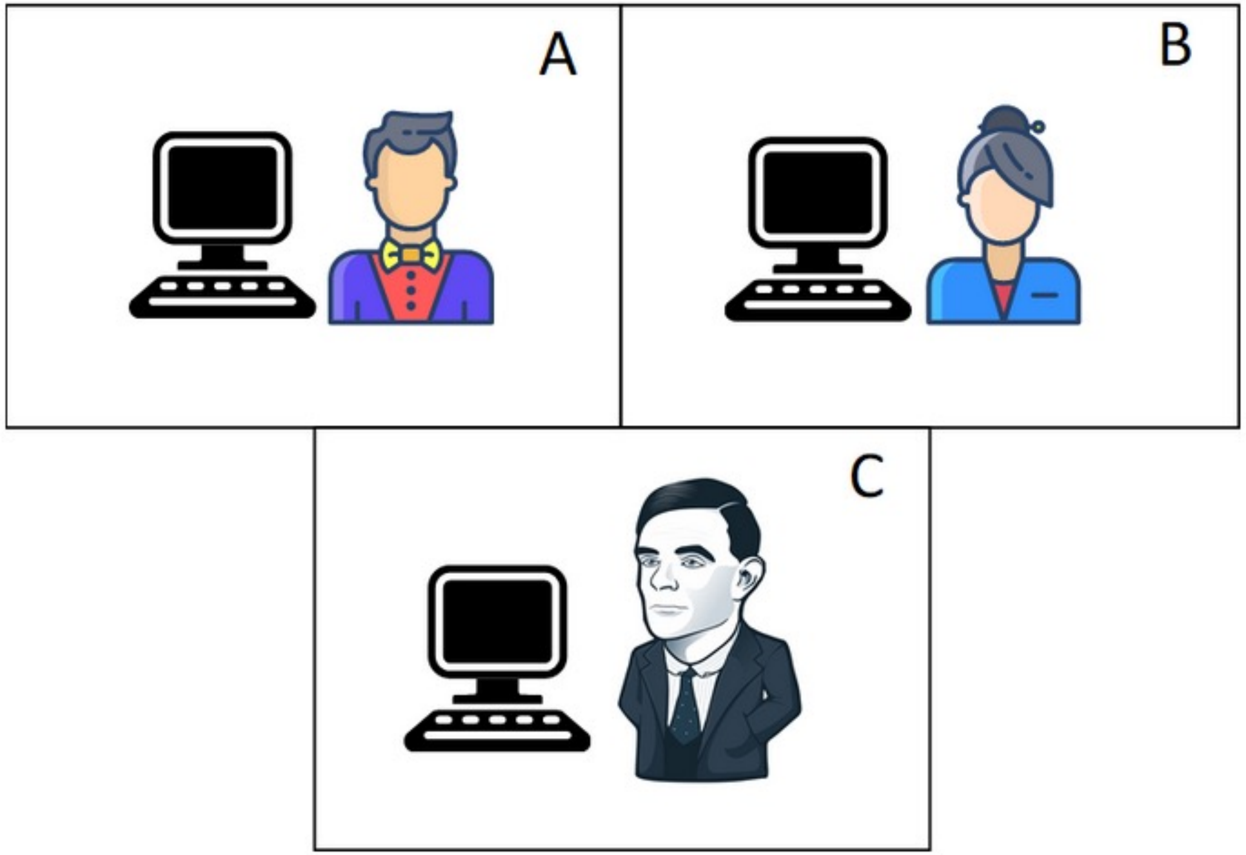
- *Can machines think ?* — Alan Turing (1912–1954)
- « Can a machine do what we as thinking entities can do?
- In other words, *can a machine mimic or imitate a person*? The answer to this question lies within ***The Imitation Game***.

- A. M. TURING, I.—COMPUTING MACHINERY AND INTELLIGENCE, *Mind*, Volume LIX, Issue 236, October 1950, Pages 433–460, https://doi.org/10.1093/mind/LIX.236.433



The Imitation Game

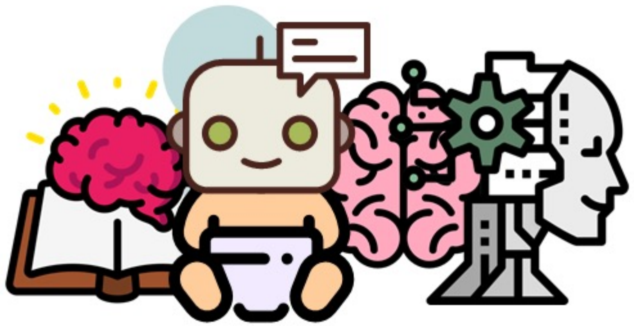
- Man (A), Woman (B), Interrogator (C)
- => can only communicate using their computer
- The goal of the game is for C to discover who is the male and who is the female.
- The goal of A, in this case, is to make C fail => fool him into thinking that he is the female.
- ***what will happen when a machine takes the role of A in this game?***
- **This is the essence of the Turing Test:** an interrogator has a conversation with a certain entity, which can either be a human or a machine.
- If the interrogator is not able to tell if the entity it was interacting with is a machine or a human, **then this machine is said to have passed the Turing Test.**



https://howtolearnmachinelearning.com/articles/what-is-the-turing-test/

Learning Machines

- If we want to imitate an adult human mind, we should somehow **replicate the process that has taken place in such a mind**, which he says, is made up of three components:
  - The initial state of the mind, at birth.
  - The education to which this mind has been subjected.
  - The experience (different from education, as that coming from the environment) to which the mind has been exposed.
- The goal here is to create a program that replicates the mind of a child, and then educate it — **make it learn** — in order for it to reach the characteristics of the adult brain.
- https://howtolearnmachinelearning.com/articles/what-is-the-turing-test/



Some Machine Learning Applications

- Email Spam/Ham filter
- Character/Digit recognition
- Face recognition on your phone/computer for example
- Self-driving cars
- In NLP:
  - Language Translation
  - Social Media Monitoring
  - Chatbots/Dialogue Agents
  - Targeted advertizing
  - Hiring and Recruitment
  - Voice assistants
  - Grammar Checkers

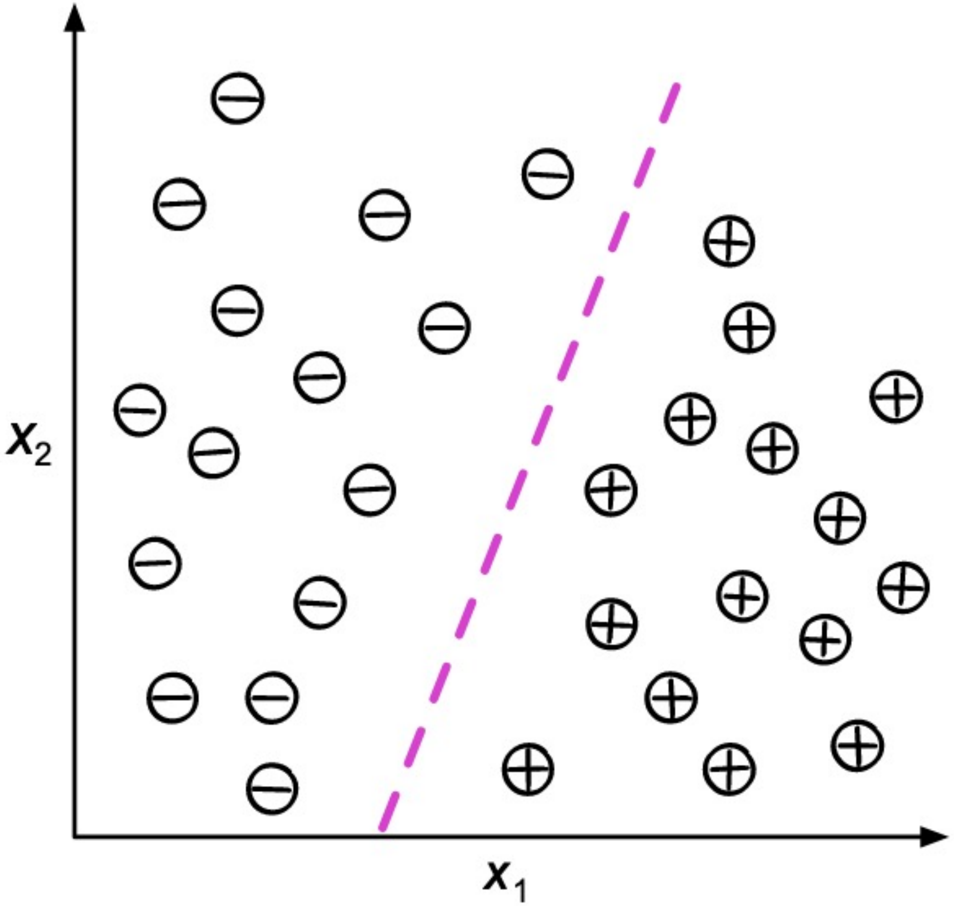
https://www.analyticsvidhya.com/blog/2020/07/top-10-applications-of-natural-language-processing-nlp/

Categories of Machine Learning

Supervised Learning

- Labeled data
- Direct feedback
- Predict outcome/future

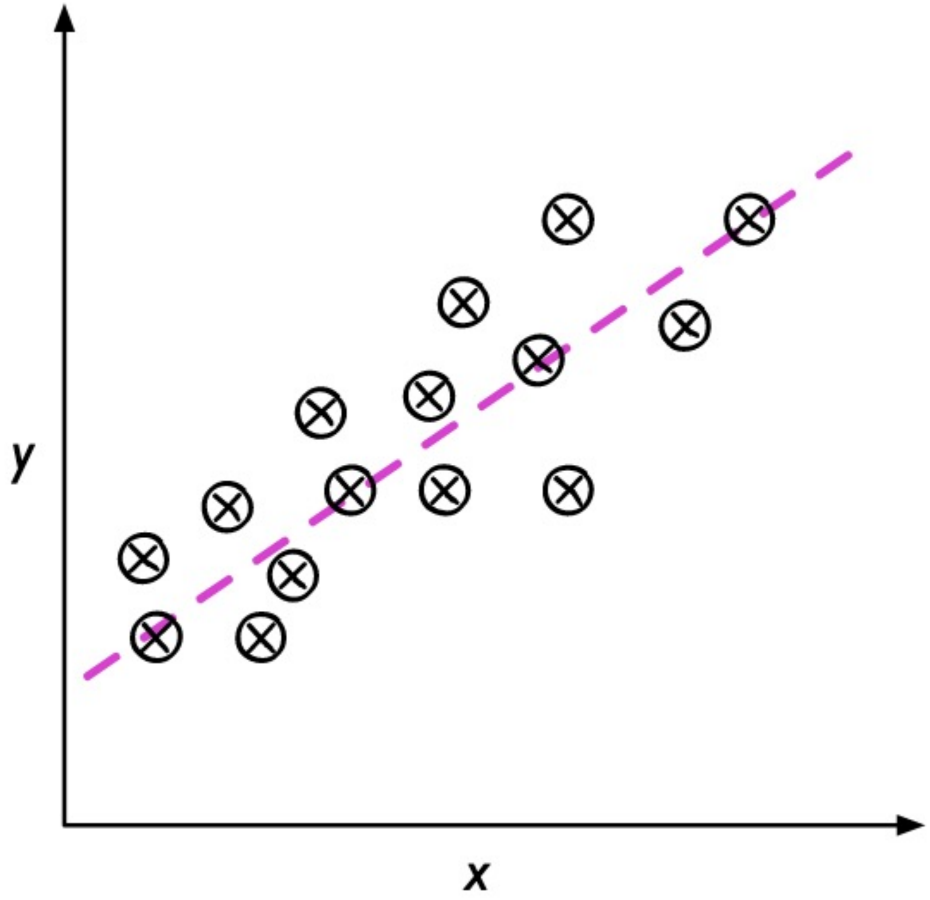
Supervised Learning Sub-category: Classification



Example : Sports car vs. Regular car
Sentiment
English vs. Another language
Spam vs. Ham…

Use boundary to predict the class of a new data point, axes are features : goal for the algorithm is to draw the boundary such that it gets most data points in the correct class.

Supervised Learning Sub-class: Regression



Examples : Housing
Temperature
Sentence Similarity…

Predict targets which are continuous values. Given an input feature x, we want to predict the output y.

Categories of Machine Learning

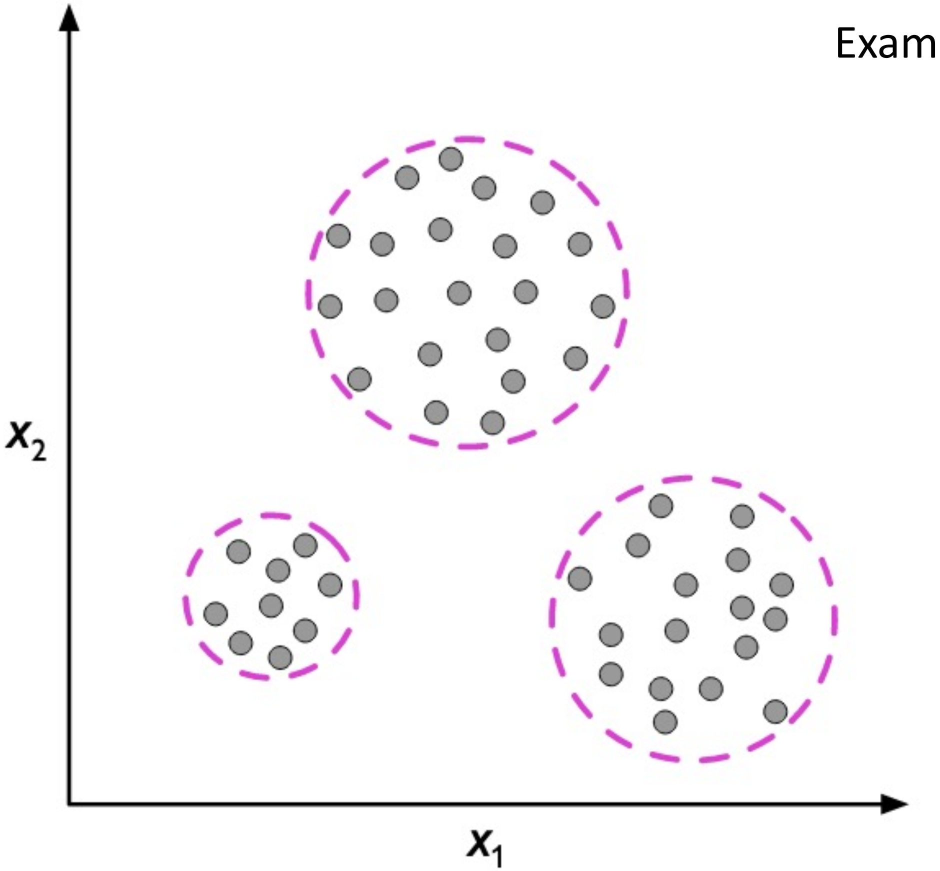
Supervised Learning

- Labeled data
- Direct feedback
- Predict outcome/future

Unsupervised Learning

- No labels/targets
- No feedback
- Find hidden structure in data

Unsupervised Learning Example : Clustering



Examples: finding clothes sizes
word-sense disambiguiation
finding similar users on youtube…

Different dots… Some appear to be grouped together (clusters), want our algorithm to « make sense » of the data, find patterns in the data, when we don't have any label info.

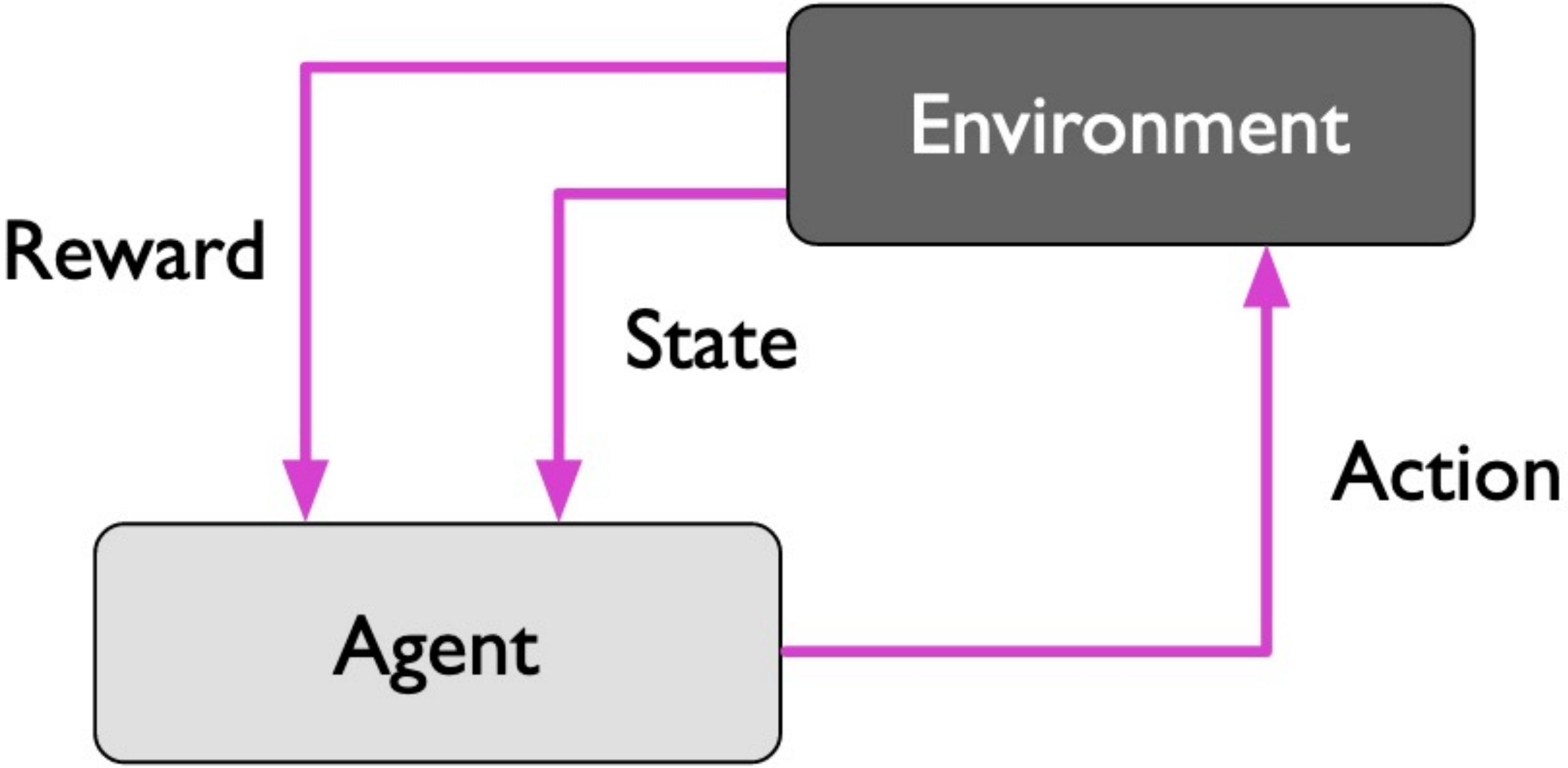
Categories of Machine Learning

Supervised Learning	› Labeled data › Direct feedback › Predict outcome/future
Unsupervised Learning	› No labels/targets › No feedback › Find hidden structure in data
Reinforcement Learning	› Decision process › Reward system › Learn series of actions

Learn with limited feedback : you don’t have the right answer, just signals to tell you if you are on the right track or not, ie. rewards

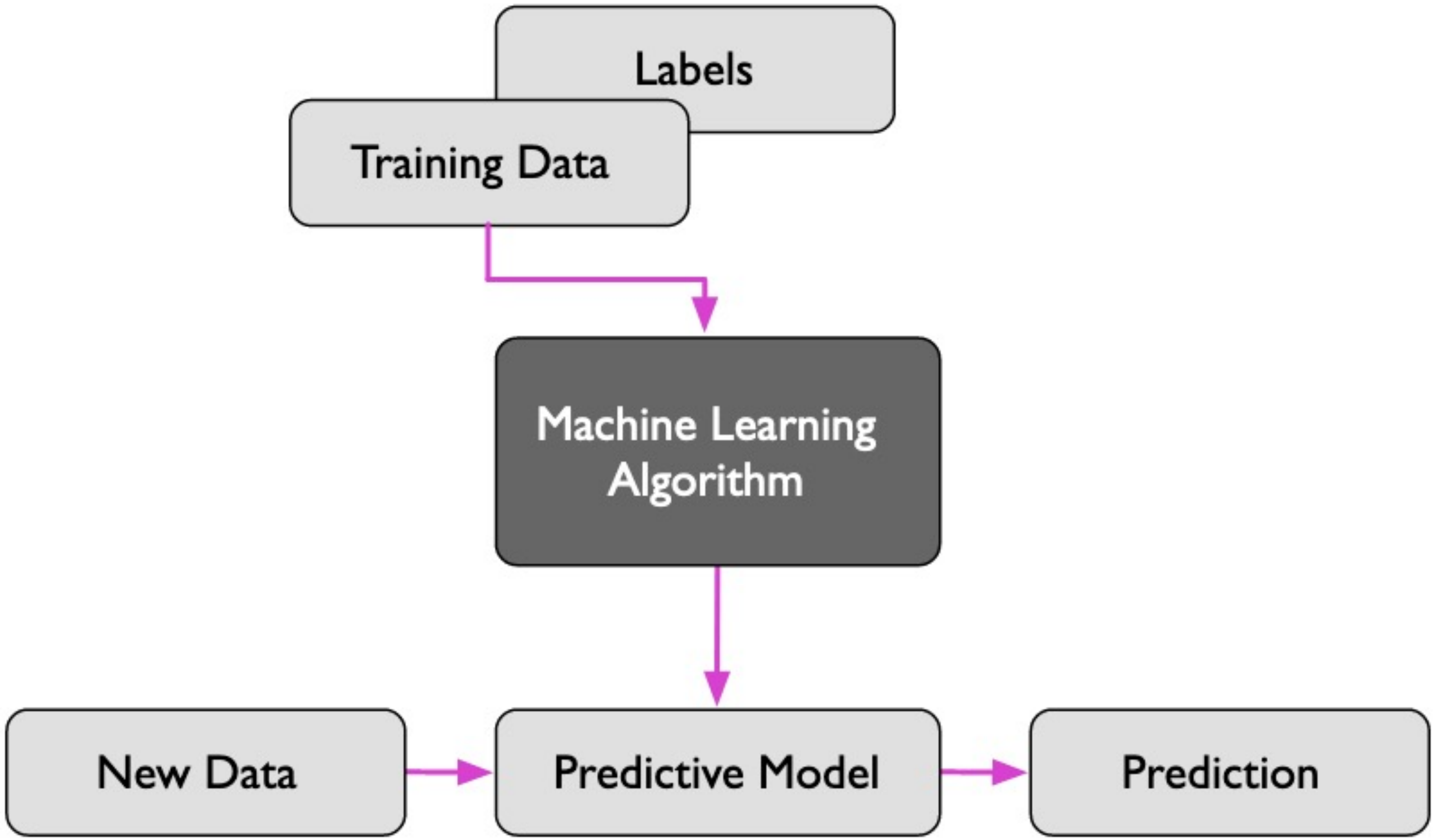
Reinforcement Learning Paradigm

GridWorld example, chess, video games (starcraft, atari games…), robotics etc…



RL Hide and Seek Demo OpenAI

Supervised Learning Workflow Overview



Supervised Learning Formal Notations

Training set: $\mathcal{D} = \{\langle \mathbf{x}^{[i]}, y^{[i]} \rangle, i = 1, \dots, n\},$

Unknown function: $f(\mathbf{x}) = y$

Hypothesis: $h(\mathbf{x}) = \hat{y}$

Classification | **Regression**

$h : \mathbb{R}^m \rightarrow \{0,1,2\}$ | $h : \mathbb{R}^m \rightarrow \mathbb{R}$

We want to **map the input** vectors of features to an output. The **original mapping** or function is **unknown** and the predictive model serves as an **estimate** or hypothesis of **that original function**.

Data Representation

$$\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_m \end{bmatrix}$$

Feature vector

Data Representation

- Design Matrix, each row represents 1 training example, i.e 1 feature vector transposed (what the T stands for). Common representation for datasets.
- Pay attention to the bold font as well: **bold => vector**, vs.a single value variable when the font is normal.

$$\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_m \end{bmatrix}$$

Feature vector

$$\mathbf{X} = \begin{bmatrix} \mathbf{x}_1^T \\ \mathbf{x}_2^T \\ \vdots \\ \mathbf{x}_n^T \end{bmatrix}$$

Data Representation Design Matrix Made Explicit

$$\mathbf{X} = \begin{bmatrix} \mathbf{x}_1^T \\ \mathbf{x}_2^T \\ \vdots \\ \mathbf{x}_n^T \end{bmatrix}$$

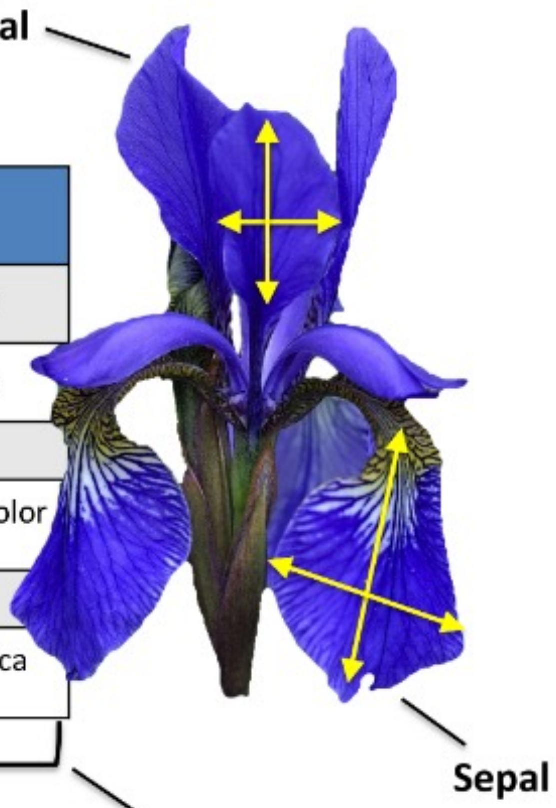
$$\mathbf{X} = \begin{bmatrix} x_1^{[1]} & x_2^{[1]} & \cdots & x_m^{[1]} \\ x_1^{[2]} & x_2^{[2]} & \cdots & x_m^{[2]} \\ \vdots & \vdots & \ddots & \vdots \\ x_1^{[n]} & x_2^{[n]} & \cdots & x_m^{[n]} \end{bmatrix}$$

Extremely Popular Dataset Example: The Iris Dataset

$m =$ ___

$n =$ ___

	Sepal length	Sepal width	Petal length	Petal width	
1	5.1	3.5	1.4	0.2	Setosa
2	4.9	3.0	1.4	0.2	Setosa
			...		
50	6.4	3.5	4.5	1.2	Versicolor
			...		
150	5.9	3.0	5.0	1.8	Virginica



Very intuitively, we basically have flower measurements and want to predict the flower Species, that's all !

Data Representation: Labels

$$\mathbf{y} = \begin{bmatrix} y^{[1]} \\ y^{[2]} \\ \vdots \\ y^{[n]} \end{bmatrix}$$

A vector to represent labels is also generally used.

ML Terminology

- **Training example**: A row in the table representing the dataset. Synonymous to an observation, training record, training instance, training sample (in some contexts, sample refers to a collection of training examples).
- **Feature**: a column in the table which represents a particular aspect of the dataset.
- **Targets**: What we want to predict.
- **Output / prediction**: use this to distinguish from targets;
  here, means output from the model.

Classes of Machine Learning Algorithms

- Generalized linear models (e.g., logistic regression)
- Support vector machines (e.g., linear SVM)
- Artificial neural networks (e.g., multilayer perceptron)
- Tree- or rule-based models (e.g., decision trees)
- Ensembles (e.g., Random Forest)
- Instance-based learners (e.g., k-nearest neighbors)