Outline

1. What is Machine Learning??
2. The Wonders of Machine Learning
3. Data, Models and ML Tasks
4. **Supervised Learning**
    1. Regression
    2. Classification
5. Unsupervised Learning
    1. Dimensionality Reduction
    2. Density Estimation

Notation

$x^1 = [1, 2, 3]$
$x^2 = [7, 8, 9]$
$x^2_2 = 8$

$\begin{pmatrix} 1.3 \\ -7.6 \\ 5.9 \end{pmatrix} \in \mathbb{R}^3$

- $\mathbb{R}$: real numbers, $\mathbb{R}_+$: Positive reals, $\mathbb{R}^d$: d-dimensional vector of reals.
- $\mathbf{x}$: vector. x_j: j^{th} co-ordinate. $\|\mathbf{x}\|$: Length of vector $\mathbf{x}$.

$x = \begin{bmatrix} 1 \\ 2 \\ 7 \end{bmatrix}$

- $\mathbf{x}^1, \mathbf{x}^2, \ldots, \mathbf{x}^n$: Collection of n vectors.

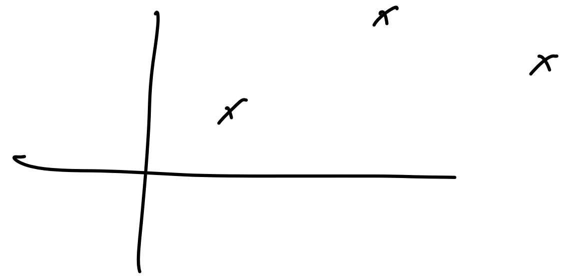
$x_3 = 7$

- x^i_j : j^{th} co-ordinate of i^{th} vector.

$\|x\|^2 = x_1^2 + x_2^2 + \ldots + x_d^2$

- $(x_1)^2$: Square of the first co-ordinate of the vector $\mathbf{x}$
- $\mathbf{1}(2 \text{ is even}) = 1$, $\mathbf{1}(2 \text{ is odd}) = 0$.

Supervised Learning



- Supervised learning is curve-fitting.

$\in \mathbb{R}^d$

- Given $\{(\mathbf{x}^1, y^1), (\mathbf{x}^2, y^2), \ldots, (\mathbf{x}^n, y^n)\}$
- Find a model f such that $f(\mathbf{x}^i)$ is ‘close’ to y^i

f is a function

Regression

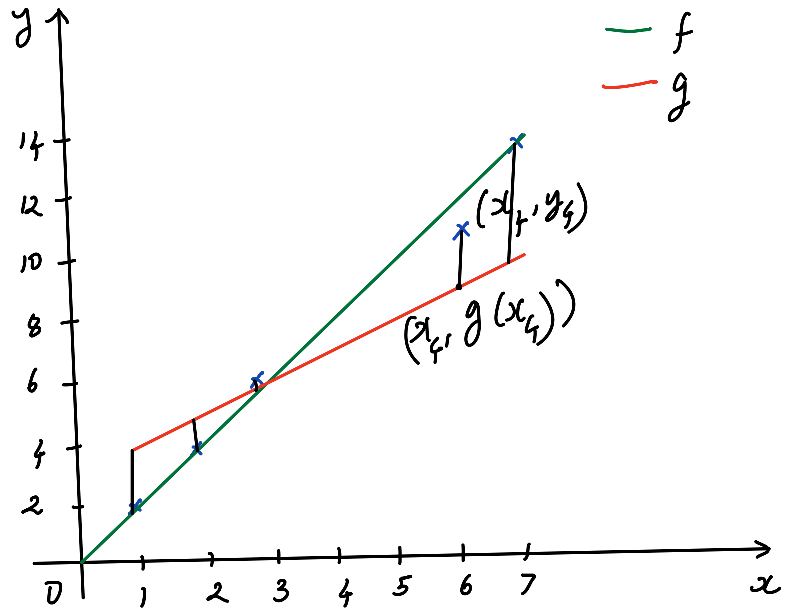
- E.g. Predict house price from room, area, distance.
- Training data: $\{(\overset{\in \mathbb{R}^3}{\mathbf{x}^1}, \overset{\in \mathbb{R}}{y^1}), (\mathbf{x}^2, y^2), \ldots, (\mathbf{x}^n, y^n)\}$
- $\mathbf{x}^i \in \mathbb{R}^d, y^i \in \mathbb{R}$
- Algorithm outputs a model $f : \mathbb{R}^d \to \mathbb{R}$
- Loss$[f] = \frac{1}{n} \sum_{i=1}^{n} (f(\mathbf{x}^i) - y^i)^2$ = Squared loss
- $f(\mathbf{x}) = \underbrace{\mathbf{w}^\top \mathbf{x} + b}_{\text{Linear Parameterisation}} = \sum_{j=1}^{d} w_j x_j + b$

$= w_1$ (# rooms) + w_2 (area) + w_3 (distance) + b

Regression Illustration 1

$d = 1$

x	y	f	g
[1]	2.1	2	4
[2]	3.9	4	5
[3]	6.2	6	6
[6]	11.5	12	9
[7]	13.9	14	10



$f(x) = 2x_1$

$g(x) = x_1 + 3$

$$\text{Loss}[f] = \frac{1}{5}\left((2-2.1)^2 + (4-3.9)^2 + (6-6.2)^2 + (12-11.5)^2 + (14-13.9)^2\right)$$

$$= \frac{1}{5}(0.3)$$

$$\text{Loss}[g] = \frac{1}{5}\left((4-2.1)^2 + (5-3.9)^2 + (6-6.2)^2 + (9-11.5)^2 + (10-13.9)^2\right)$$

Regression Illustration 2

Rooms	Area	Distance	Price	$f = 2 * \text{Rooms} - 0.5 * \text{dist}$	$g = \text{Rooms} + 2 * \text{distan}$
3	9	1.9	**5.0**	5.05	6.8
2	7	2.1	**3.2**	2.95	6.2
4	12	2.8	**6.6**	6.6	9.6
5	16	0.9	**9.8**	9.5	6.8
5	15	3.1	**8.5**	8.5	11.2
4	11	1.6	**6.9**	7.2	7.2