Introduction to Supervised Learning

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What Is Supervised Learning?

- One of the most prevalent forms of ML
  - Teach a computer to do something, then let it use its knowledge to do it
  - Also called “learning with a teacher”
- Other forms of ML
  - Unsupervised learning (“learning without a teacher”)
  - Reinforcement learning (“learning with (delayed) feedback”)

Example: Spam detection

- Input: Emails received

- Output: “Spam”, or “No spam”

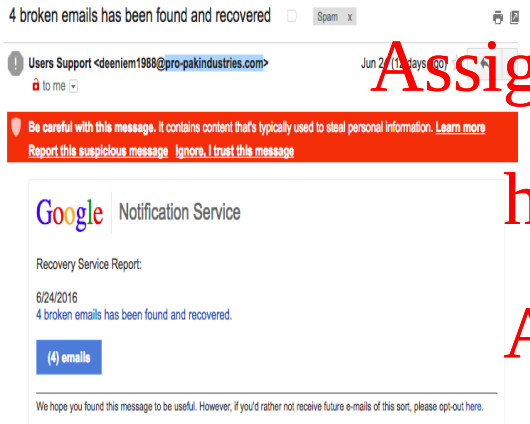
Example: Stock price prediction

- Input: Historical records of stock prices

- Output: Next day's stock price

Spam detection

- Input: Emails received



- Output: “Spam”, or “No spam”
- This is a **classification** problem. The output has 2 possible values

Stock price prediction

- Input: Historical records of stock prices

- Output: Next day’s stock price
- This is a **regression** problem. The output is a real value.

Types of supervised learning

- Regression
- Classification
  - Binary
  - Multi-class
  - …

Supervised learning

Task:

- Given some **input** *x*.
- Predict an appropriate **output** *y*.

*Want: a **function** f such that f(x)=y*

Have: examples of input-output pairs $(\boldsymbol{x}^{(1)}, y^{(1)}), (\boldsymbol{x}^{(2)}, y^{(2)}), \ldots, (\boldsymbol{x}^{(n)}, y^{(n)})$

Supervised learning helps find a good f.

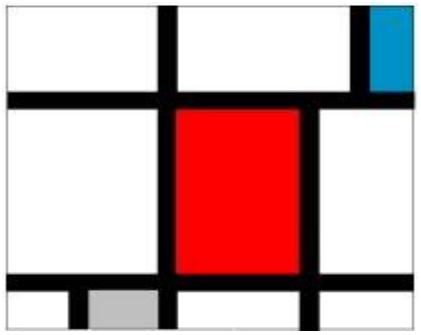
Training data

- Supervised learning needs annotated data for training:

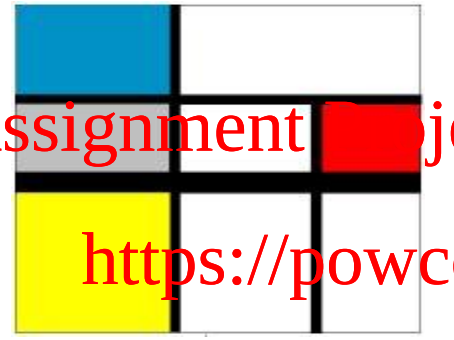
  in the form of examples of (Input, Output) pairs

- After training completed,
  - you present it with new Input that it hasn't seen before
  - It needs to predict the appropriate Output

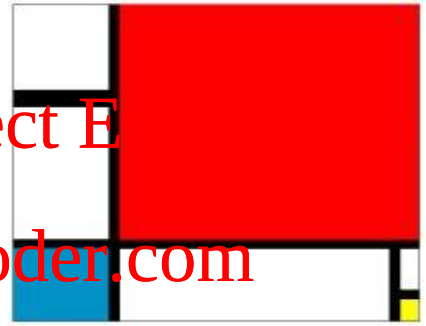
Is painting 8 a genuine Mondrian?



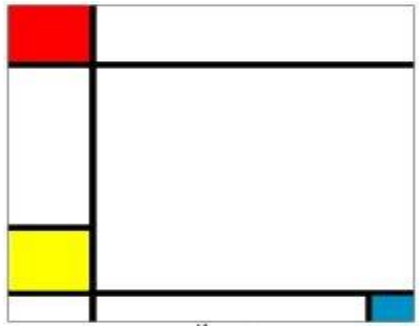
1. No



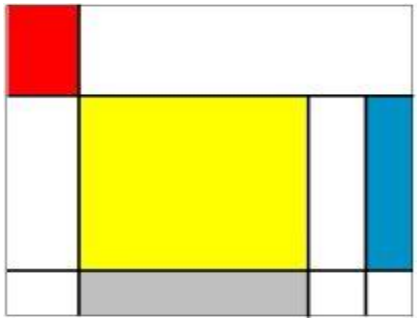
2. No



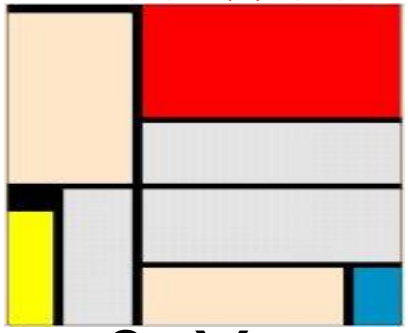
3 Yes



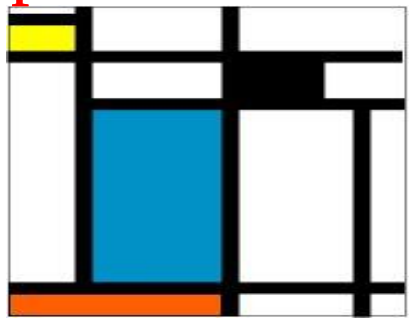
4. Yes



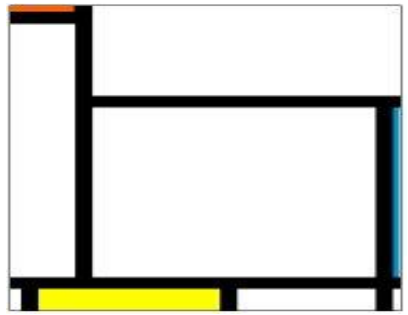
5.No



6. Yes



7. No



8. ?

Annotated training data

Attributes

Labels

Examples

Number	Lines	Line types	Rectangles	Colours	Mondrian?
1	6	1	10	4	*No*
2	4	2	8	5	*No*
3	5	2	7	4	Yes
4	5	1	8	4	Yes
5	5	1	10	5	*No*
6	6	1	8	6	Yes
7	7	1	14	5	*No*

Painting 8

Number	Lines	Line types	Rectangles	Colours	Mondrian?
8	7	2	9	4	**???**

How quick will your team complete a project?

(programming language)	(team expertise)	(estimated size)	…	(required effort)
Java	low	1000	…	10 p-month
C++	medium	2000	…	20 p-month
Java	high	2000	…	8 p-month
…	…	…	…	…

General notation we will use

(programming language)	(team expertise)	(estimated size)	…	(required effort)
		$x^{(1)}$		$y^{(1)}$
		$x^{(2)}$		$y^{(2)}$
		$x^{(3)}$		$y^{(3)}$
…	…	…	…	…

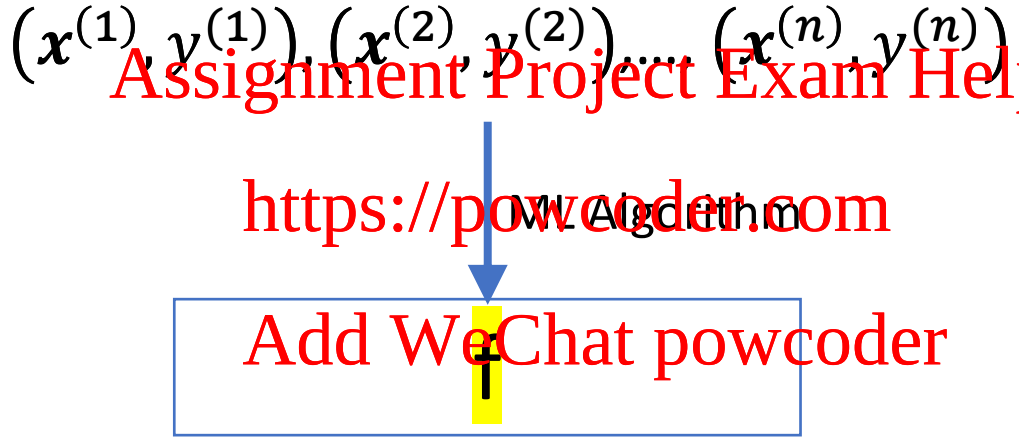
Vector notation

$$x^{(i)} = \left(x_1^{(i)}, x_2^{(i)}, x_3^{(i)}, \ldots, x_d^{(i)}\right)$$

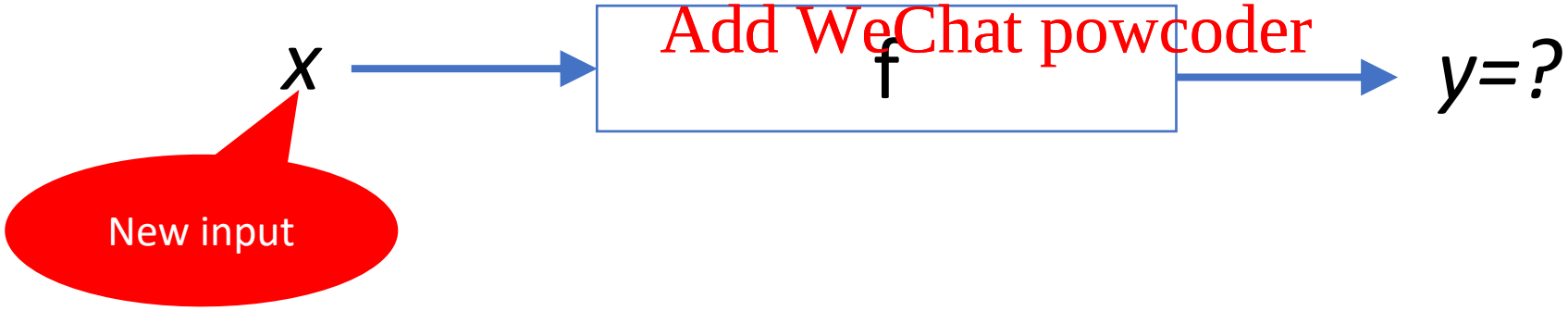
The input of the *i*-th example

Attributes

Workflow of supervised learning:
1. Training phase

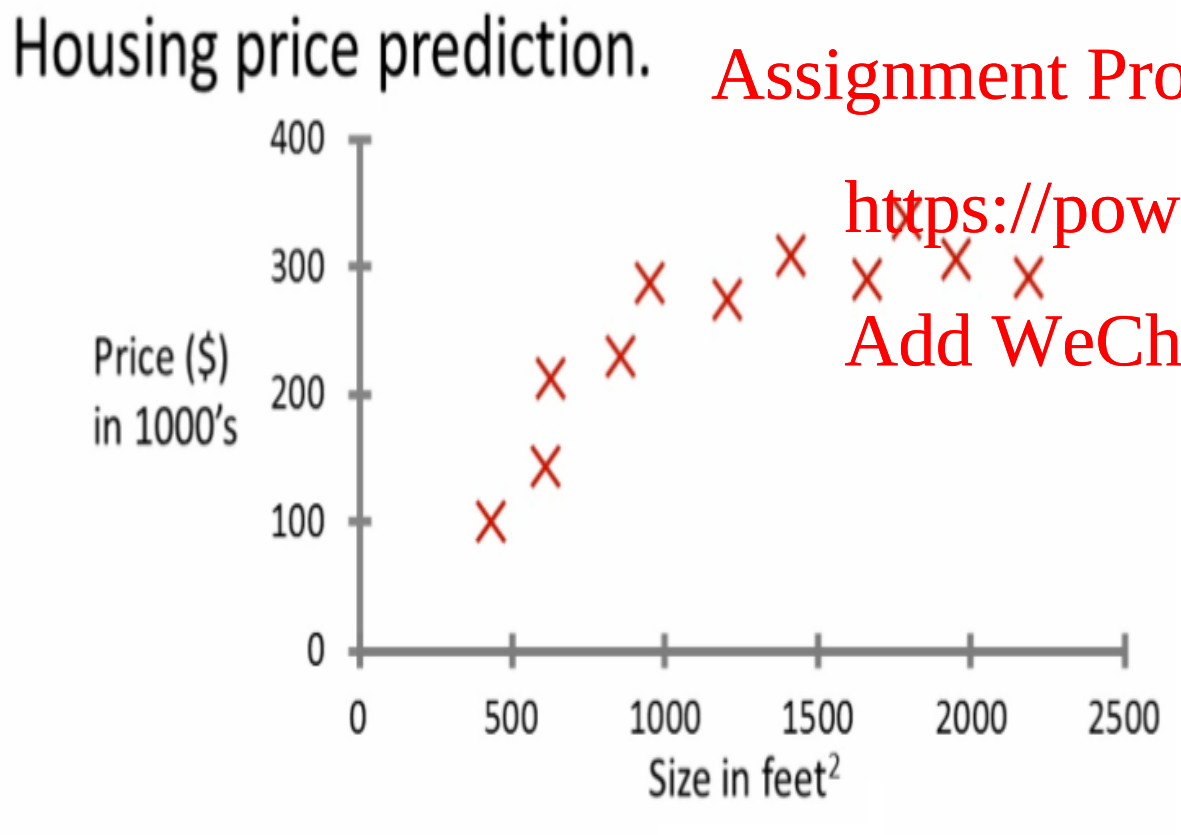


Workflow of supervised learning:
2. Test phase & use



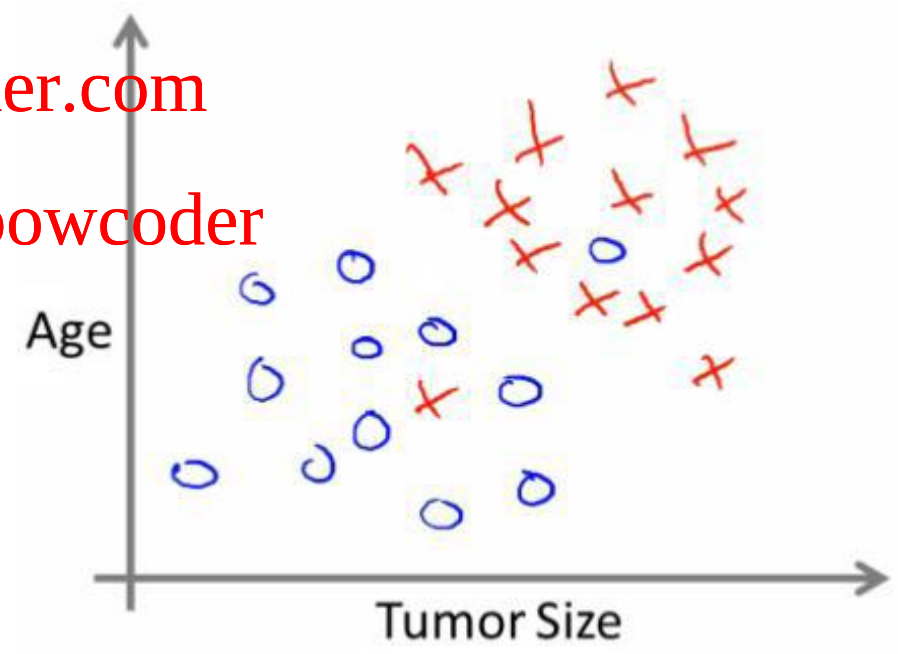
Pictorially

- Regression problem



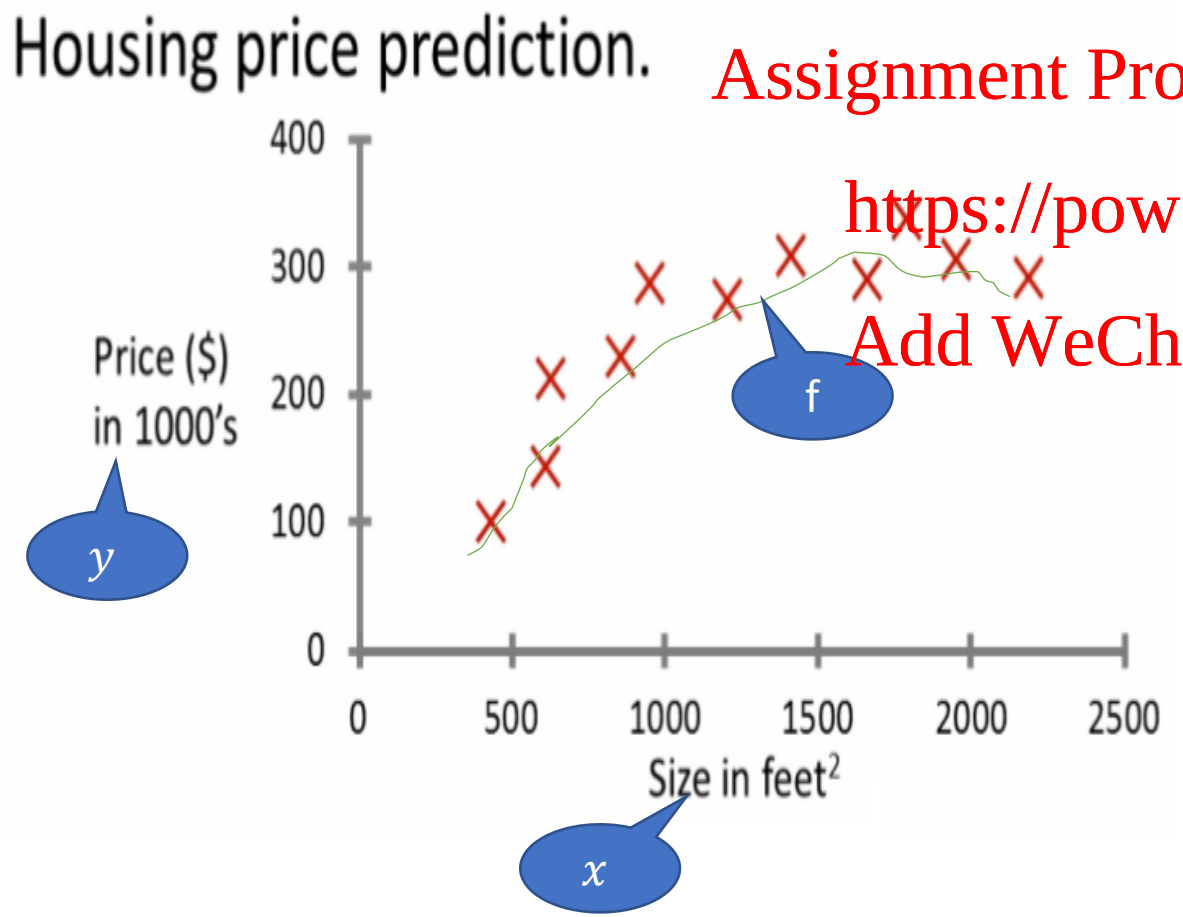
- Classification problem

Breast cancer prediction



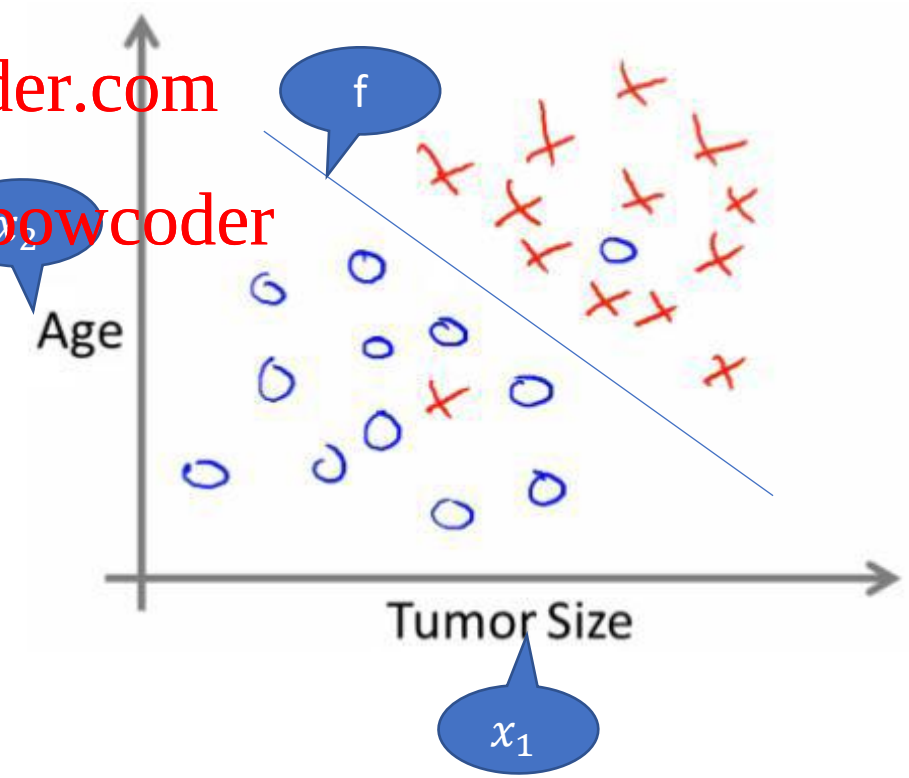
Pictorially

- Regression problem



- Classification problem

Breast cancer prediction



Terminology in Supervised Learning

- Input = attribute(s) = feature(s) = independent variable
- Output = target = response = dependent variable
- function = hypothesis = predictor

Pause. Is this some magic?

So…

- there is this unknown function we're after
- we are given the function values at *n* specific points only (training set)
- is it really possible to find out the function values at other points?

- No!
- Not unless we make the right assumptions about the unknown function
- Each ML algorithm, implicitly or explicitly, makes assumptions.
- There is a zoo of ML algorithms, there is no best ML algorithm
- Our goal is to focus on few of them, and understand how they work

Applications of supervised learning

- Handwriting recognition
  - When you write an envelope, algorithms can automatically route envelopes through the post
- Computer vision & graphics
  - When you go out during lockdown, object detection & visual tracking algorithms can automatically detect compliance with the rules
- Bioinformatics
  - Algorithms can predict protein function from sequence
- Human-computer interaction
  - Intrusion detection algorithms can recognise speech, gestures, intention

Why is ML so Prevalent?

- Generality
  - E.g. a robot learning to navigate mazes must be able to learn the layout of the maze it encounters
- Adaptability
  - E.g. a program designed to predict tomorrow's stock market must learn to adapt when conditions change from boom to bust
- Applicability
  - Often the human programmer has no idea how to program a solution to the problem (think of how you recognise your friend's face)