Week 2. Introduction to Supervised Learning

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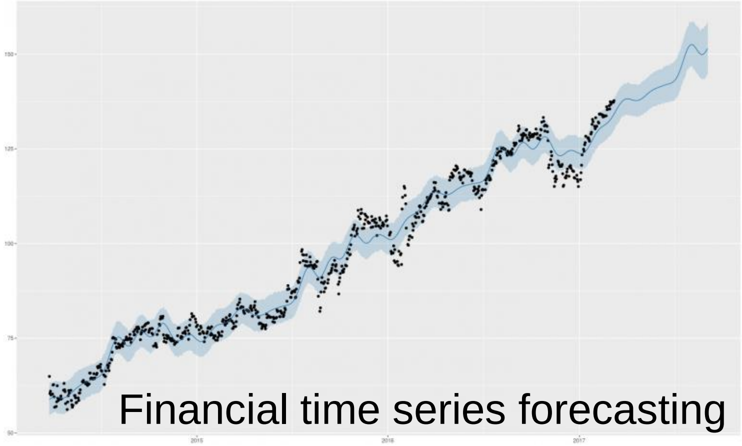
Overview

- Different forms of machine learning
- Supervised learning
- Regression and classification

Machine Learning Problems

Machine learning problems are those that require a model to be built automatically from data, e.g. to make classifications, estimations or predictions.

Speech recognition



Financial time series forecasting

Forms of Machine Learning

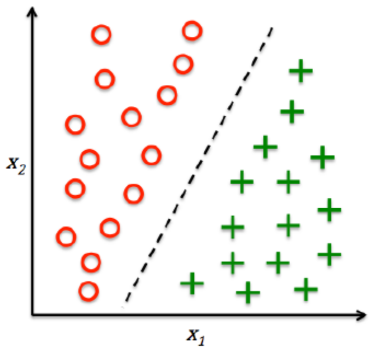
Three forms:

- Supervised learning
- Unsupervised learning
- Reinforcement learning

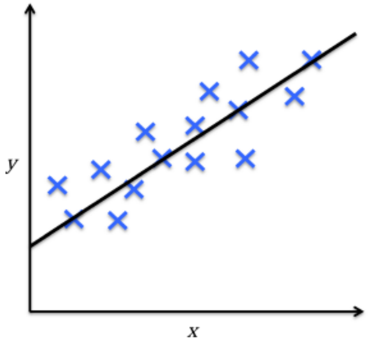
Supervised learning

- The most prevalent form
- Learning with a teacher
- Teacher: expected output, label, class, etc.
- Solve 2 types of problems:

classification



regression



Distinguishing Cats from Dogs

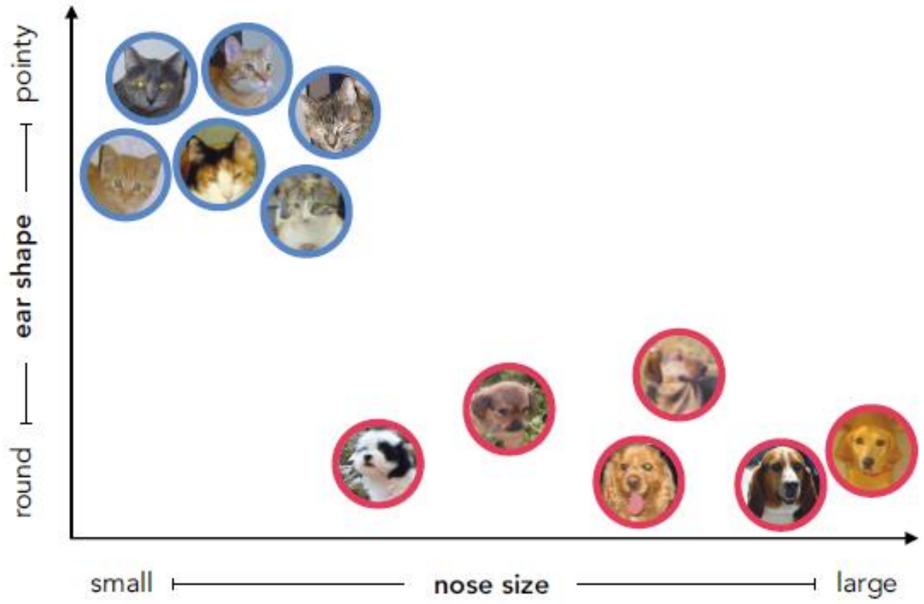


Fig 1.1/1.2 from Machine Learning Refined by Jeremy Watt

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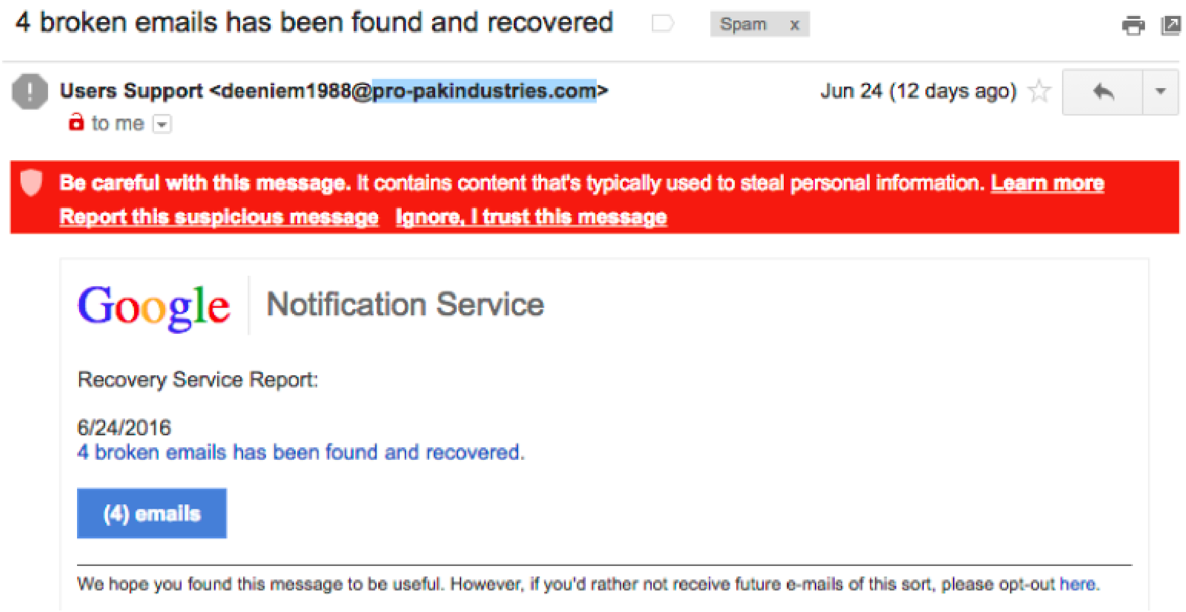
Example: Spam detection

- Input:
  Emails received

- Output:
  Spam, or not spam



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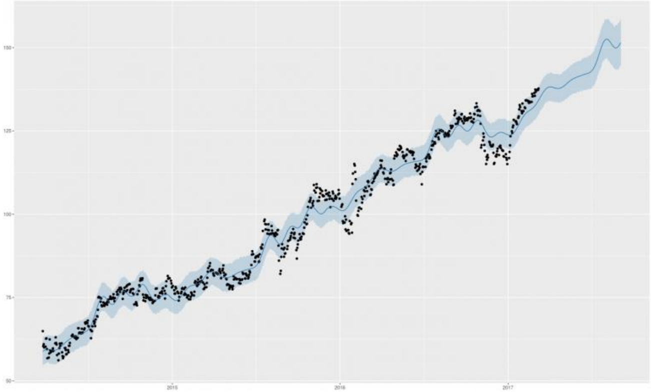
Example: Stock price prediction

- Input:
  Historical records of stock prices

- Output:
  Next day's stock price



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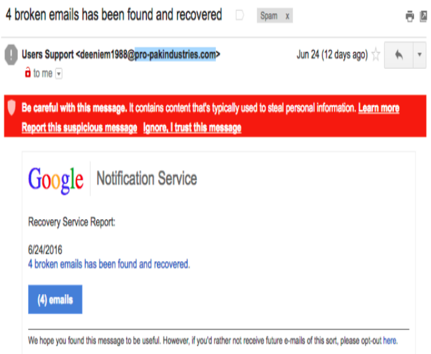
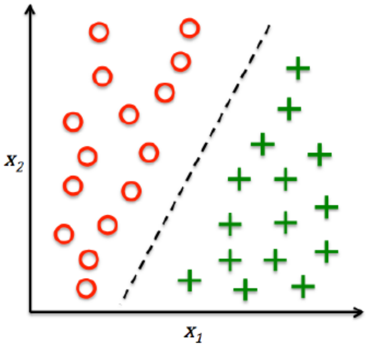
Types of supervised learning

Spam detection



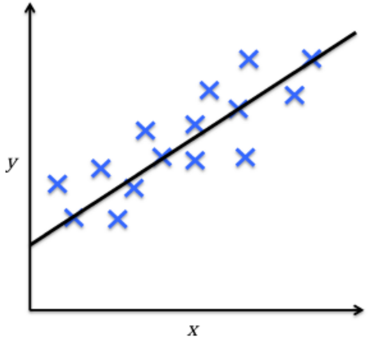


<u>Classification problem</u>

predict categorical class labels

e.g. the handwritten digit (multi-class)

Stock price prediction



<u>Regression problem</u>

Prediction of a real value

e.g. students' grade scores

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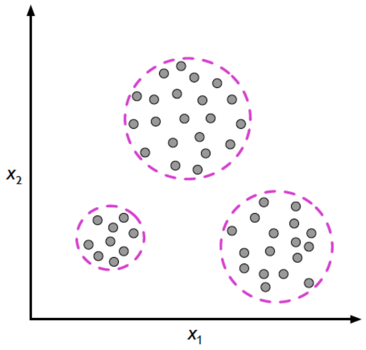
Unsupervised learning

- Learning without a teacher
- To find hidden structure/insights in data
- Clustering, e.g. product recommendation, sport strategy discovery

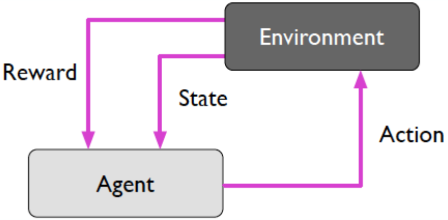


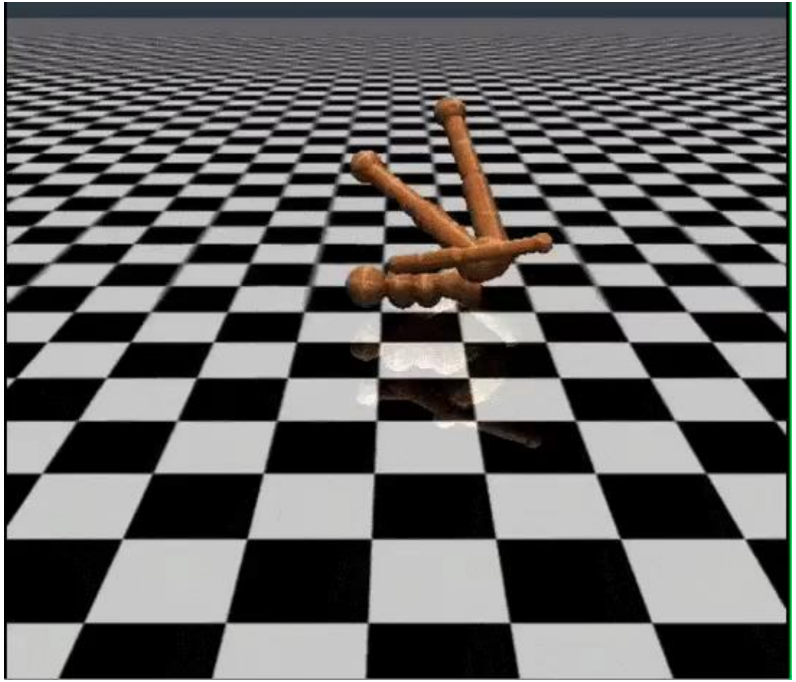
Clustering

RL

Reinforcement learning

- Learning with (delayed) feedback/reward
- Learn series of actions, e.g. chess, robots, …





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How does supervised learning work?

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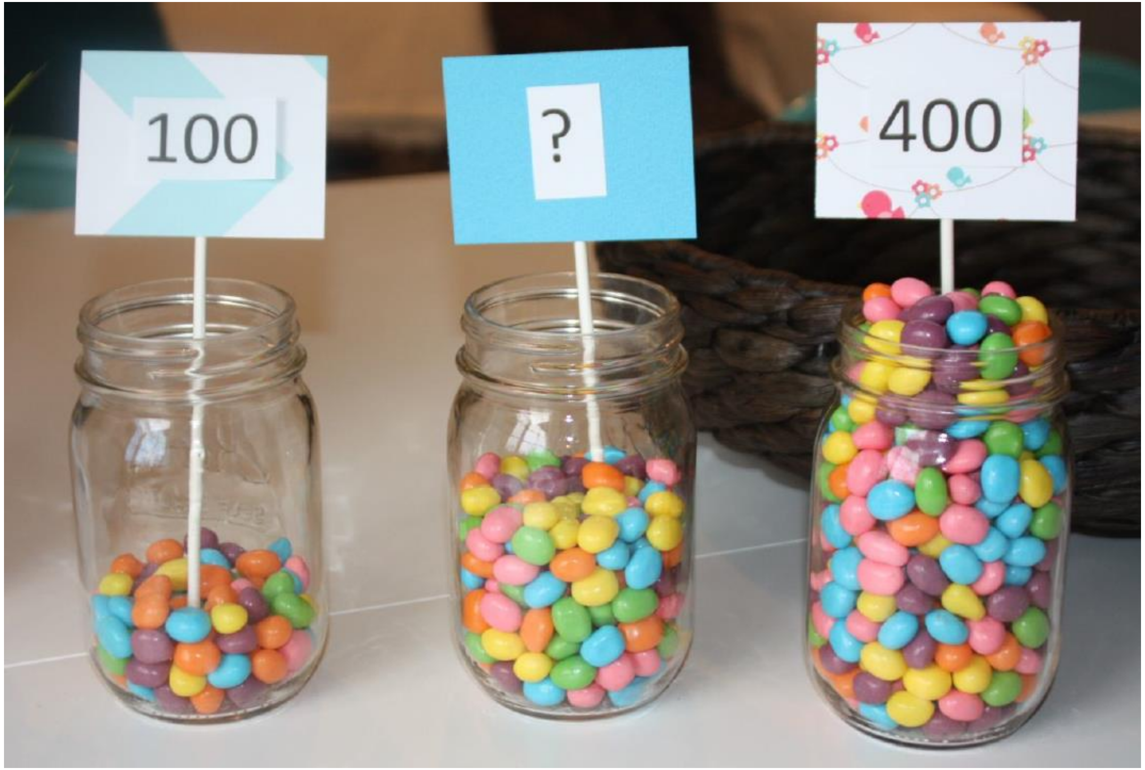

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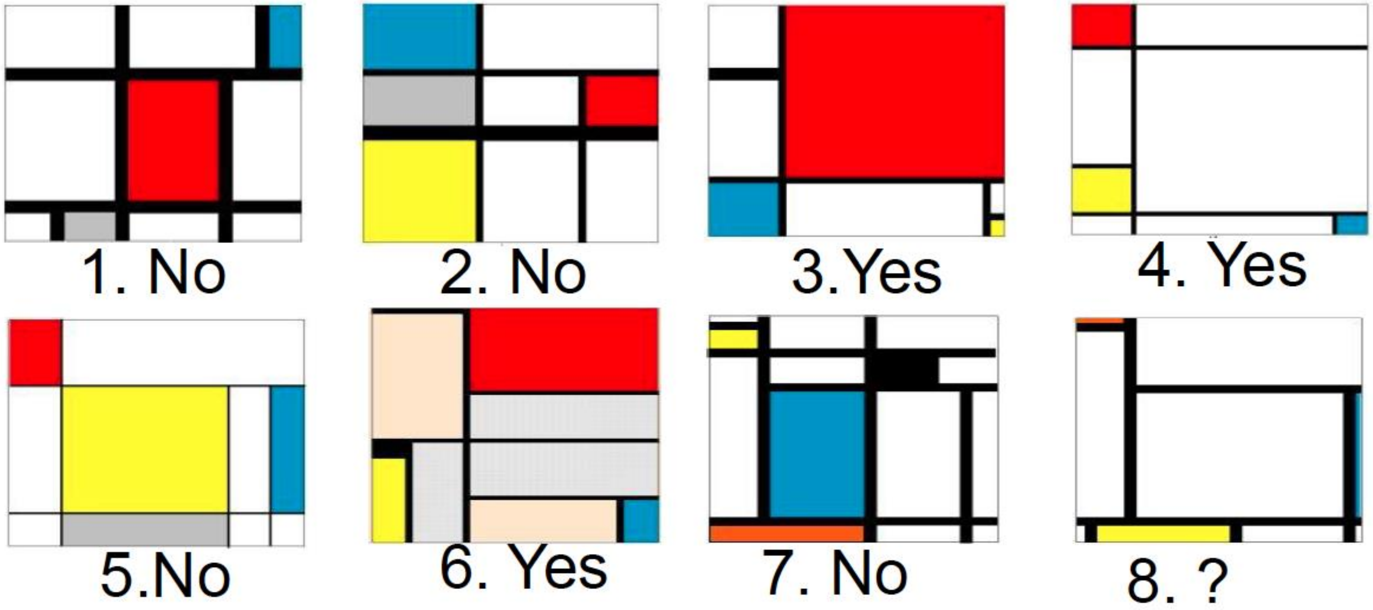
Formulate supervised learning

- Task:
  - Given some input x,
  - Predict an appropriate output y
- Goal: a function f such that $f(x) = y$

The learning process:

1) Have: examples of input-output pairs → training data
   $\left(x^{(1)}, y^{(1)}\right), \left(x^{(2)}, y^{(2)}\right), \ldots, \left(x^{(n)}, y^{(n)}\right)$
2) Supervised learning helps find a good f → training/modelling
3) Given a new input $x^{(n+1)}$, predict its output $y^{(n+1)}$ → prediction

Is painting 8 a genuine Mondrian?



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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 quickly 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 notations we often use

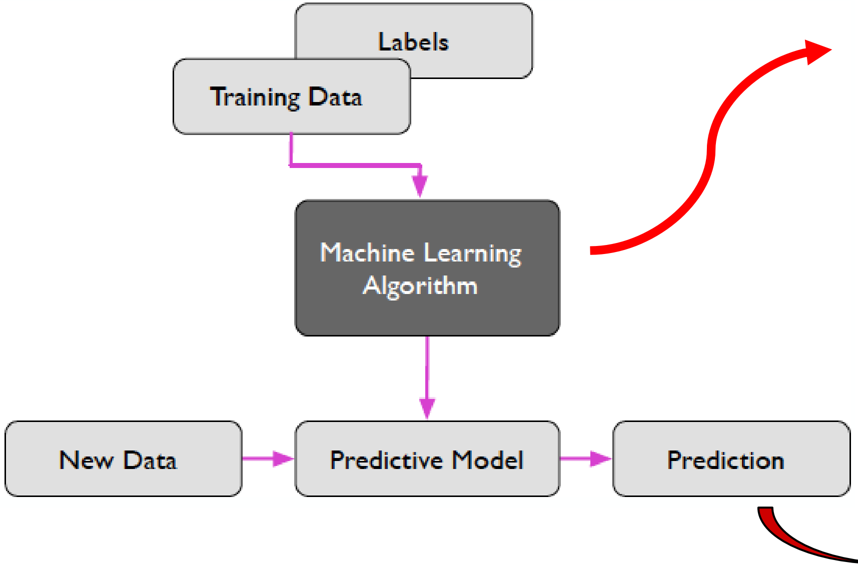
Lines	Line types	Rectangles	…	Mondrian?
$\boldsymbol{x}^{(1)}$				$y^{(1)}$
$\boldsymbol{x}^{(2)}$				$y^{(2)}$
$\boldsymbol{x}^{(3)}$				$y^{(3)}$
…				…

Vector notation:

$$\underbrace{\boldsymbol{x}^{(i)} = \left(x_1^{(i)}, x_2^{(i)}, x_3^{(i)}, \ldots, x_d^{(i)}\right)}_{\text{Attributes, d-dimensional}}$$

The input of the i-th example

Supervised learning workflow



Training phase:

$$(\boldsymbol{x}^{(1)}, y^{(1)}), (\boldsymbol{x}^{(2)}, y^{(2)}), \ldots, (\boldsymbol{x}^{(n)}, y^{(n)})$$

$$\Downarrow$$

$$f(\boldsymbol{x}) = y$$

Test/Use phase:

$$\boldsymbol{x} \rightarrow f(\boldsymbol{x}) \rightarrow y$$

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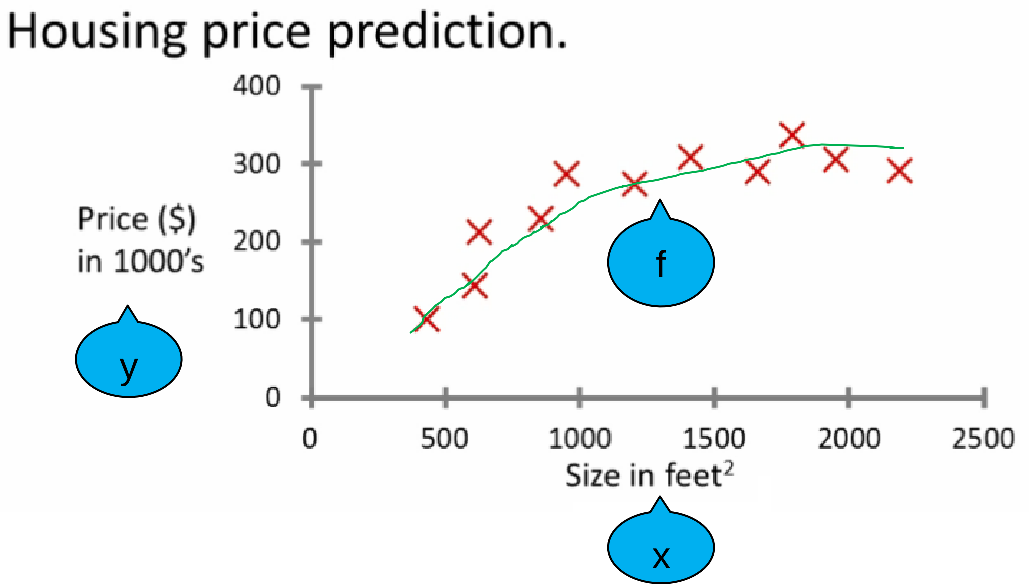
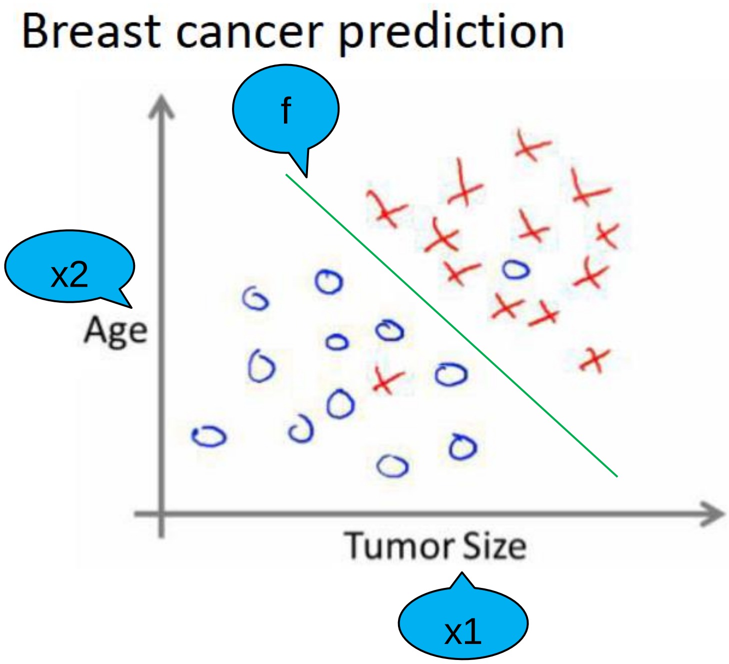
Source: Python machine learning, 2nd ed, Sebastian Raschka

Pictorially

Regression problem



Classification problem



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Terminology in supervised learning

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

Pause. Is this some magic?

So…

- There is an unknown function we are 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?

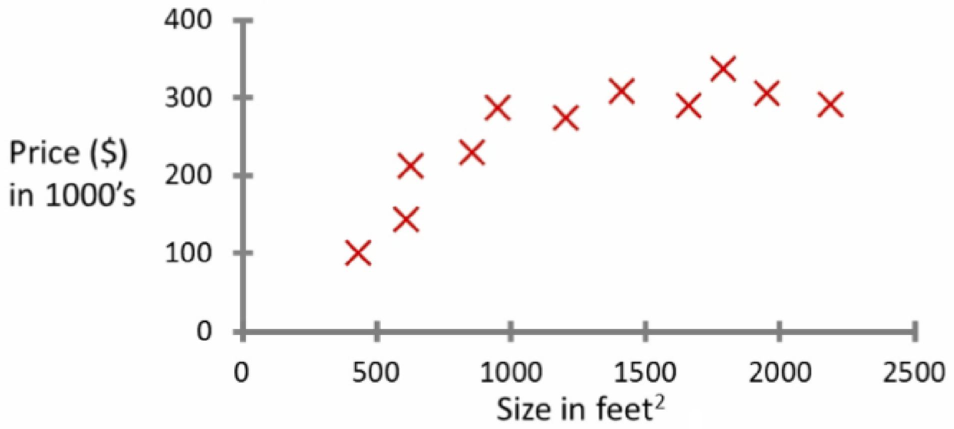
No!

- 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 one.

How many predictors are there for each case?

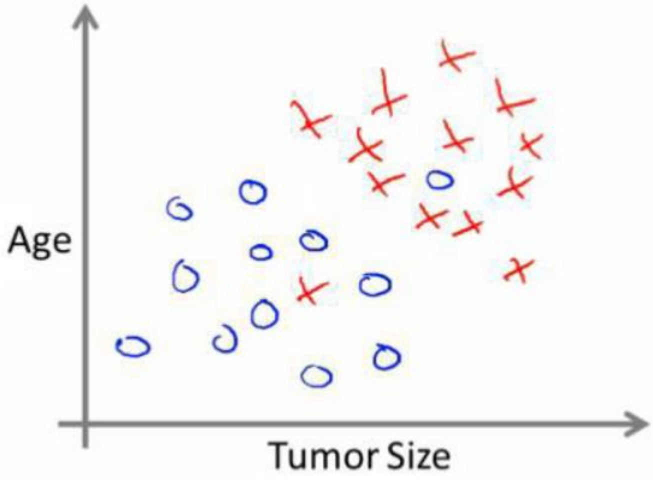
Regression problem

Housing price prediction.



Classification problem

Breast cancer prediction



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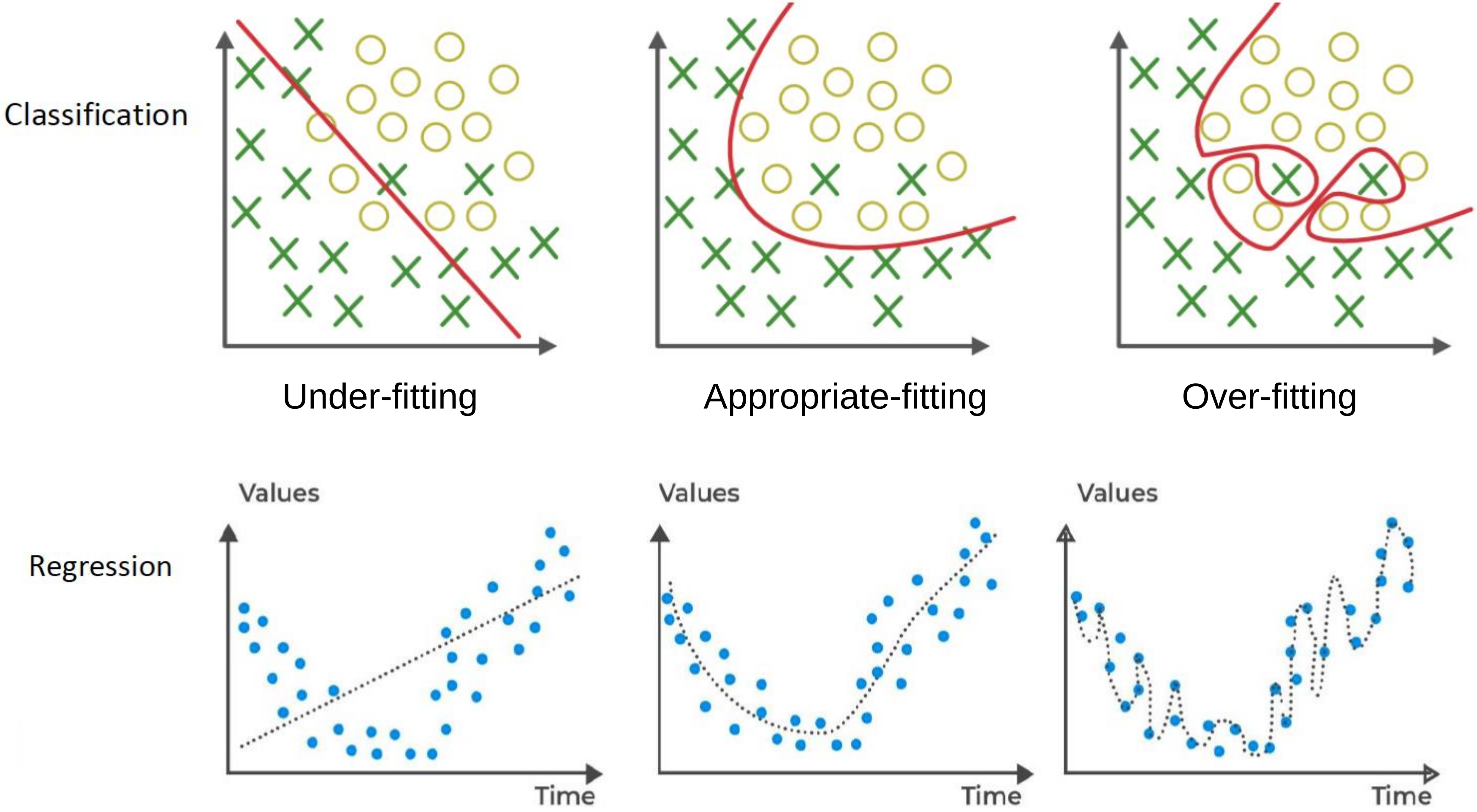

https://www.geeksforgeeks.org/regularization-in-machine-learning/

Overfitting and Underfitting

- Fitting the training data too well is BAD! Why?
- Remember the data you actually want to classify, or predict for, is not the same as the training data –so learning every irrelevant detail (noise) in a training data set will not help.
- Overfitting happens when the model is more complex than required.
- Underfitting happens when the model is simpler than required.

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 & vision tracking algorithms can automatically detect compliance with the rules.
- Bioinformatics
  - Algorithms can predict protein function from sequence.
- Human-computer interaction
  - Algorithms can recognize speech, gestures, intention.

Q/A

Teams Channel for Week2
Office Hours Tue/Thu 11am-12pm
See Canvas module homepage