FIT1043

Week 1-7

授课老师：Joe

DATA VISUALISATION

- For categorical data, standard visualisations include:
  - Frequency tables
  - Bar graphs
  - Pie charts
- For numeric data (continuous and discrete), we can use:
  - Histograms
  - Box plots

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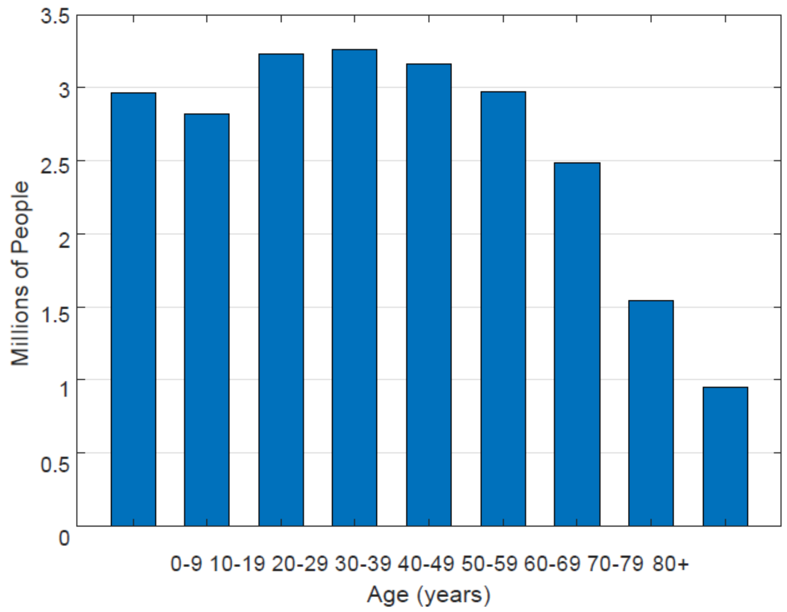
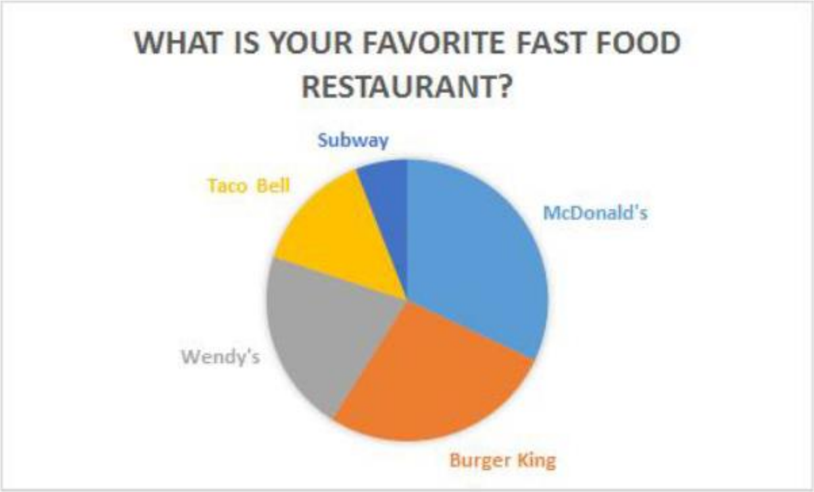
Age (years)	Number of People
0-9	2,967,425
10-19	2,818,778
20-29	3,231,395
30-39	3,265,526
40-49	3,164,712
50-59	2,977,883
60-69	2,488,396
70-79	1,540,373
80+	947,411





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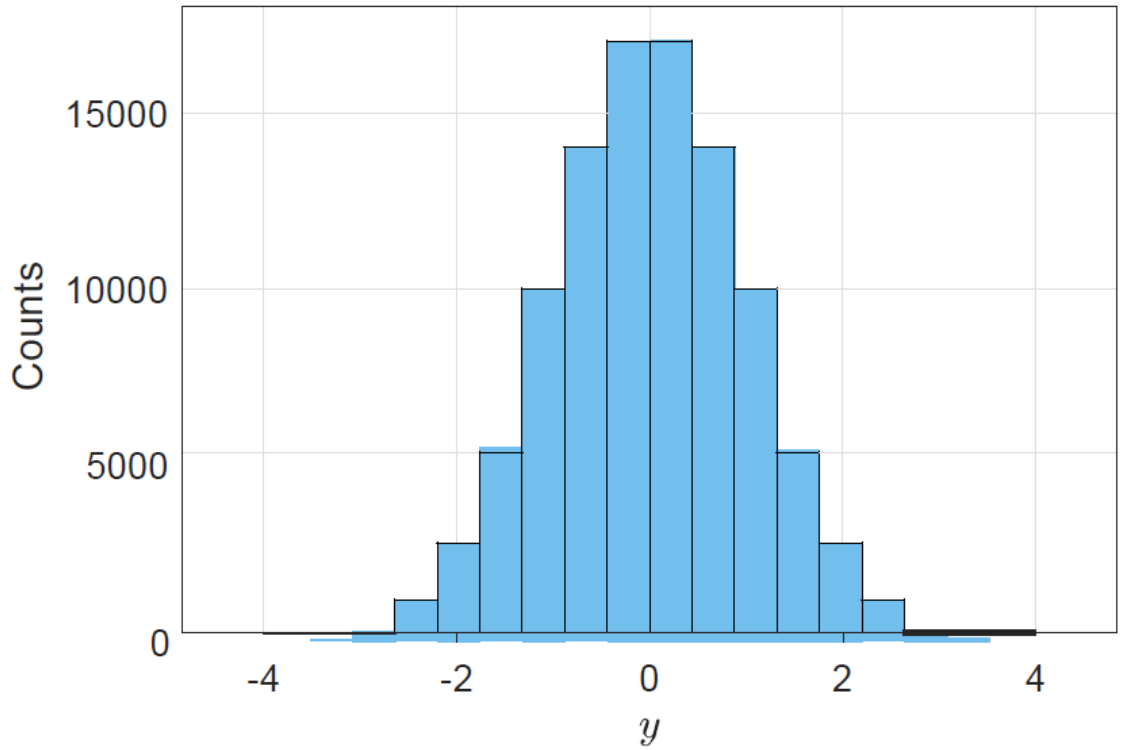

Descriptive statistics

Centrality

- Mean
- Mode
- Median

Which option is the Mean, Median and Mode of the following set of values respectively?
1,2,2,3,4,7,9

A. 4,2,3
B. 5,3,2
C. 4,3,3
D. 4,3,2

Type	Example	Result
Mean	(1+2+2+3+4+7+9) / 7	**4**
Median	1, 2, 2, **3**, 4, 7, 9	**3**
Mode	1, **2**, **2**, 3, 4, 7, 9	**2**

- The mean uses *all* the values of the sample
  - Any change to any sample changes the mean
  - The mean can be changed as much as desired by changing just one sample by a large enough amount
- The median uses at most two of the values of the sample

  Is very resistant to changes to the samples not in the middle

Percentiles

- More generally, we can define the percentiles
  - The p-th percentile is the value, $Q(\mathbf{y}, p)$ such that $p\%$ of the values of the sample are lower than $Q(\mathbf{y}, p)$
- The median is simply the 50th percentile, $Q(\mathbf{y}, 50)$
- Other important percentiles are the 1st and 3rd quartiles
  - i.e., the 25th and 75th percentiles

Spread

The most straightforward is the range

$$\mathrm{rng}(\mathbf{y}) = \max\{\mathbf{y}\} - \min\{\mathbf{y}\}$$

The most common measure of spread used is the sample standard deviation

$$s(\mathbf{y}) = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(y_j - \bar{y})^2}$$

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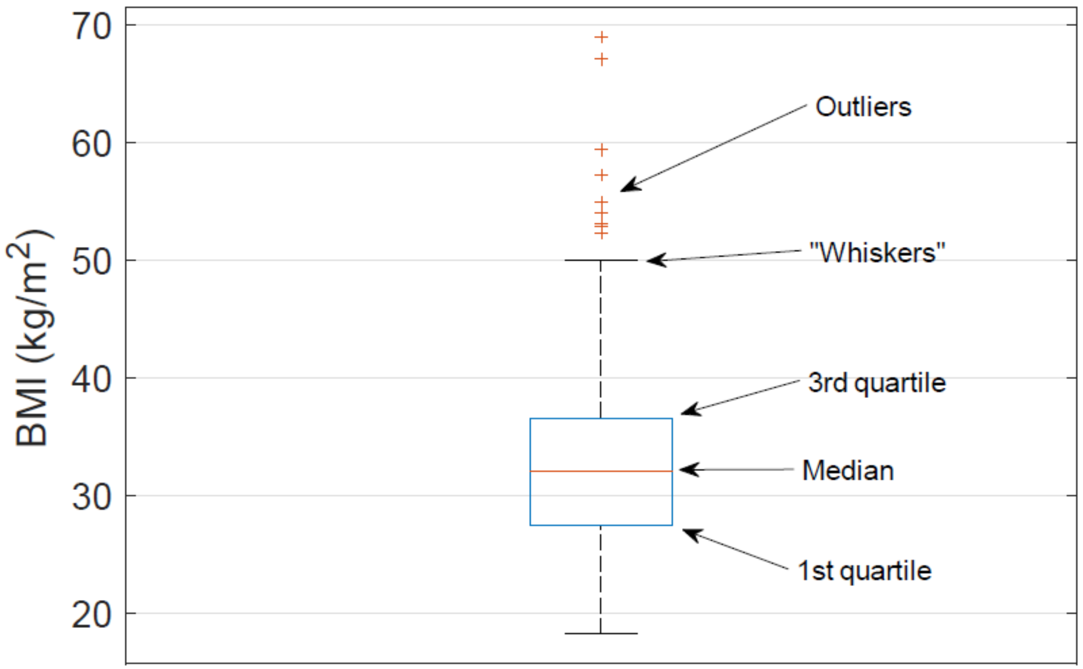

70
60
50
40
30
20
BMI (kg/m^2)
Outliers
"Whiskers"
3rd quartile
Median
1st quartile

Pearson correlation measures linear association

$$R(\mathbf{x},\mathbf{y}) = \frac{\sum_{j=1}^{n}(x_j - \bar{x})(y_j - \bar{y})}{n\, s(\mathbf{x}) s(\mathbf{y})}$$

- Correlation is always between -1 (completely negatively correlated) and 1 (completely positively correlated)
- A correlation of zero implies there is no linear association

$\Rightarrow$ does not imply no non-linear association

Remember: correlation not equal causation!

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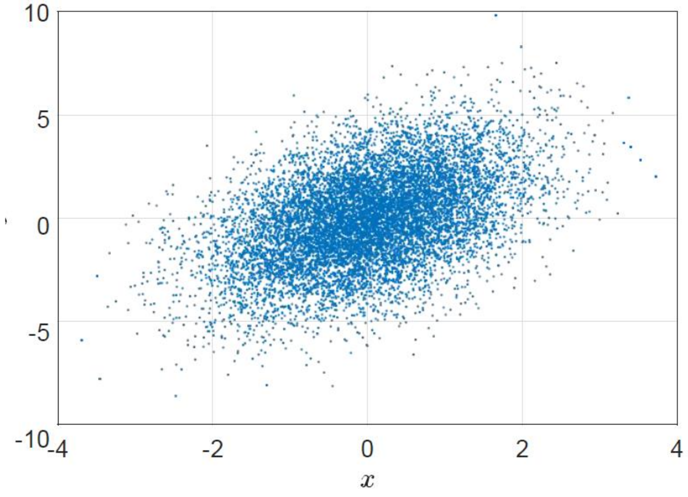
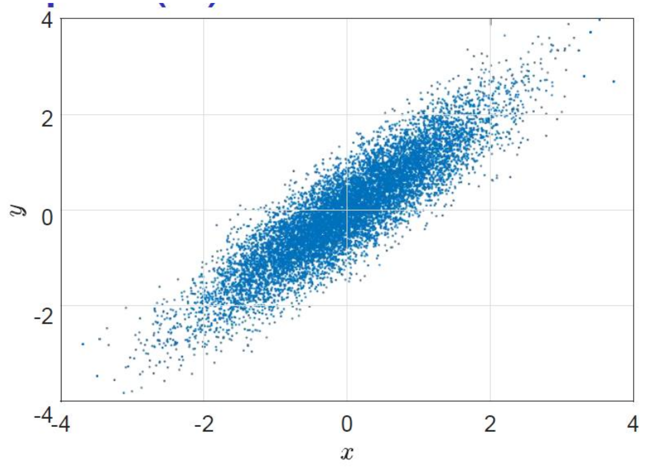
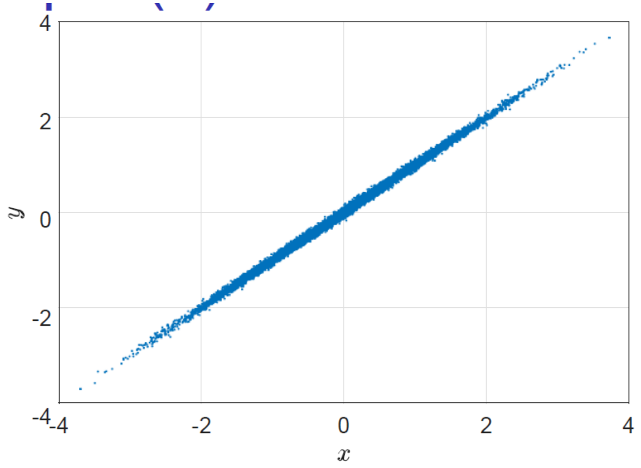




R = 0.9



R ≈ 0.999

- If **x** is categorical, and **y** is numeric, how to visualise?
- A standard approach is the side-by-side boxplot
  - Divide the data between categories, then plot boxplots for each group
  - Do the boxplots look different?
- If **x** and **y** are both categorical, we can use a side-by-side bargraph instead
  - Are the distributions/bargraphs different between categories? If so, there is a possible association

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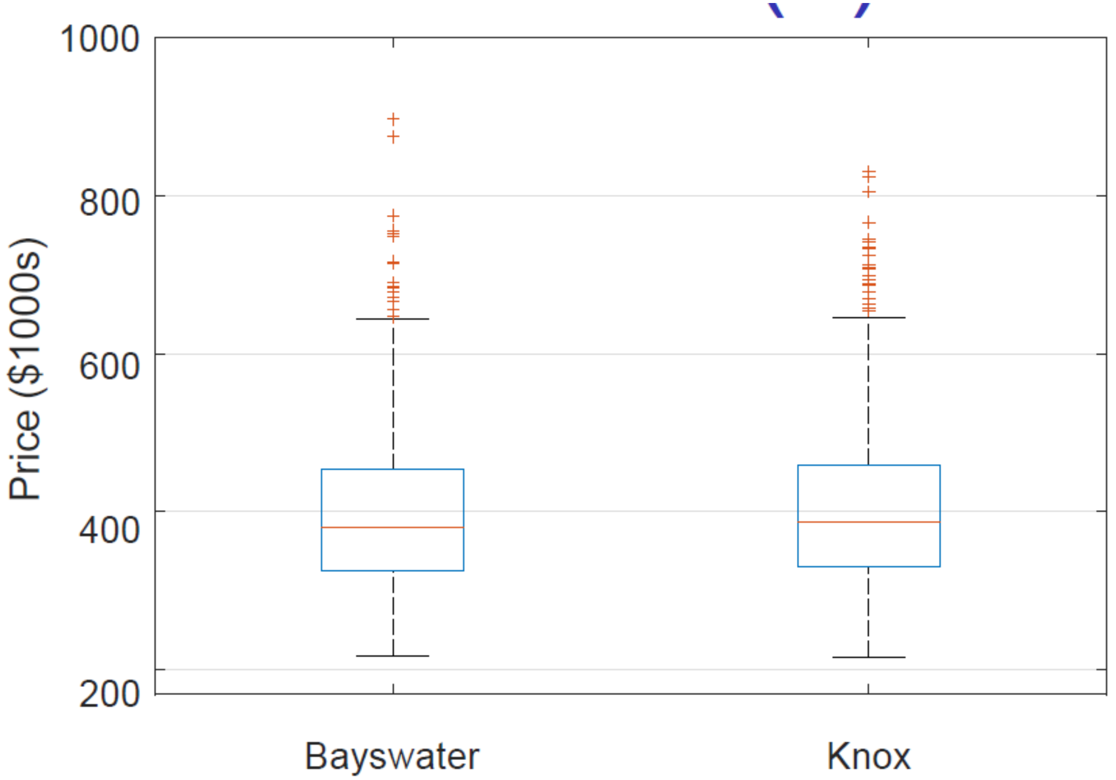

DATA WRANGLING

Sources of Data Quality Issues

- Interpretability issue
- Data format issue
- Inconsistent and faulty data
- Missing and incomplete data
- Outliers
- Duplicates

Dirty data

Mark Johnson, 31, 21/Aug/1985, 180, M, 0433010010, Melbourne VIC

Mr. Christian, Peter, 34, 21-09-1982, , M, 0433010118, Sydney NSW

Ethan Steedman, 32, 01/01/1982, 170, M, 0433210019, Sydney NSW

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Inconsistency

- common cases:
  - upper vs. lower case
  - inconsistency in domain value representation, e.g., 0 vs. No, 1 vs. Yes
- detecting and fixing
  - investigate unique domain values (`unique()`)
  - make the representation consistent, e.g., replace

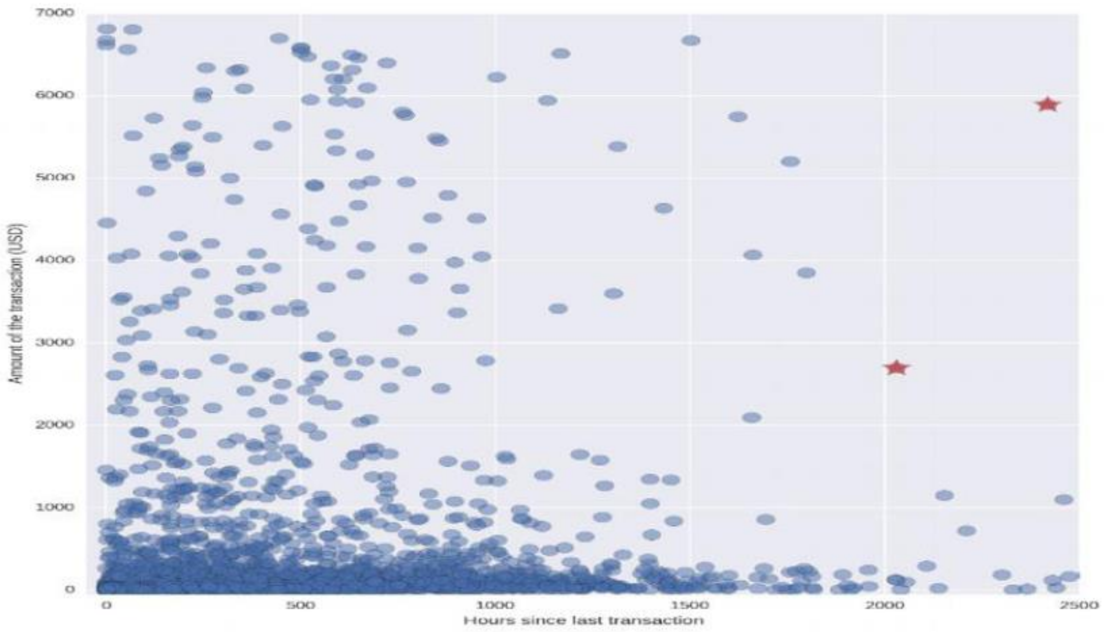
Misspelling

- investigate unique domain values (`unique()`)
- string matching
  - calculate domain value frequencies (`value_counts()`)
  - for all values, find matches for the infrequent values
  - replace infrequent values with the best match (if it exists) from the more frequent values.

Missing values

```
32,1,1,95,0,?,0,127,0,.7,1,?,?,1
34,1,4,115,0,?,?,154,0,.2,1,?,?,1
35,1,4,?,0,?,0,130,1,?,?,?,7,3
36,1,4,110,0,?,0,125,1,1,2,?,6,1
38,0,4,105,0,?,0,166,0,2.8,1,?,?,2
38,0,4,110,0,0,0,156,0,0,2,?,3,1
38,1,3,100,0,?,0,179,0,-1.1,1,?,?,0
38,1,3,115,0,0,0,128,1,0,2,?,7,1
38,1,4,135,0,?,0,150,0,0,?,?,3,2
38,1,4,150,0,?,0,120,1,?,?,?,3,1
40,1,4,95,0,?,1,144,0,0,1,?,?,2
```

Outliers

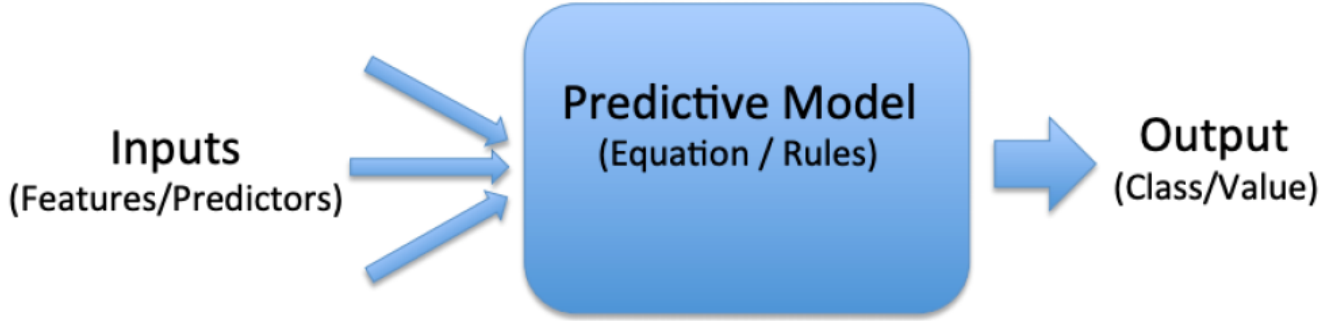

7000
6000
5000
4000
3000
2000
1000
0
Amount of the transaction (USD)
0
500
1000
1500
2000
2500
Hours since last transaction

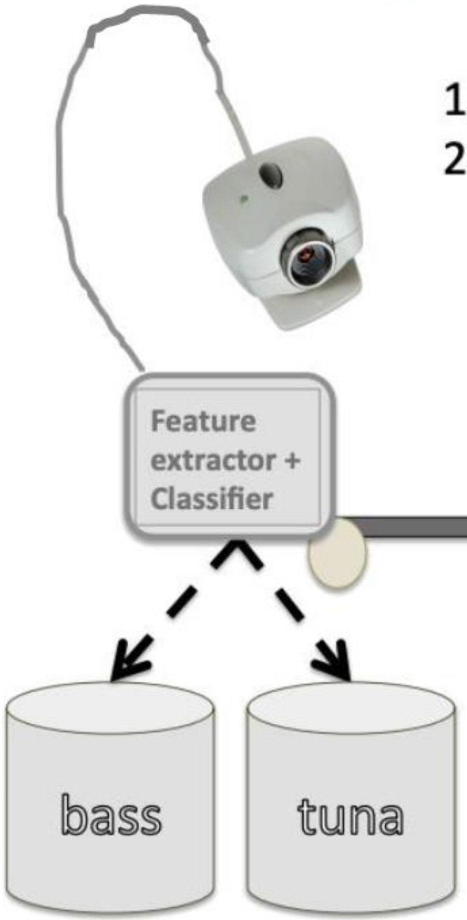
Data Analysis Theory

Predictive Models

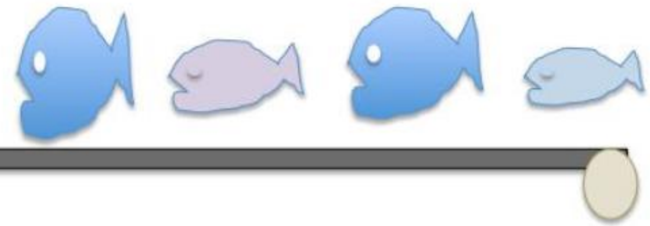
A predictive model is any model that makes a prediction

- Usually based on a set of features describing an object.
- The prediction could be:
    - A binary outcome (spam, not-spam)
    - Categorical (bass, tuna, other)
    - A real value (the age of the fish)
    - A vector of real values (probability of bass, tuna)
    - Etc.





1. Install camera to capture image of fish
2. Compute **features** of fish from image:
   - X_1: length
   - X_2: width
   - X_3: colour



3. Learn rule(s) for classifying fish
   - if $X_1/X_2<1.4$ and X_3=blue => **bass**
   - if $X_1/X_2>2.1$ and X_3=(lightblue,pink) => **tuna**
   - else => **unknown**

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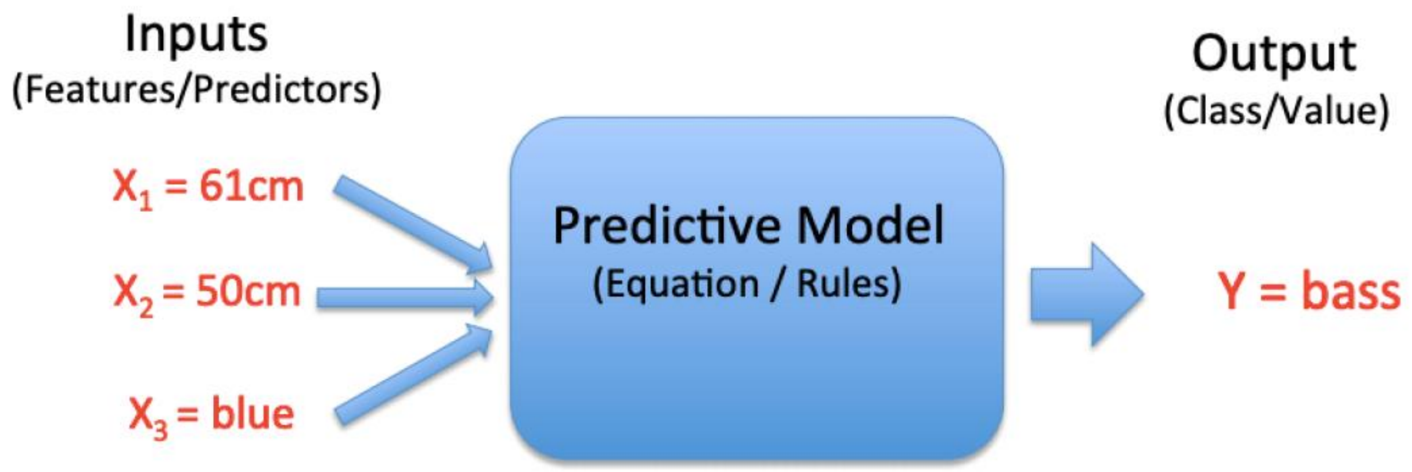
Inputs
(Features/Predictors)
X1 = 61cm
X2 = 50cm
X3 = blue
Predictive Model
(Equation / Rules)
Output
(Class/Value)
Y = bass

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- If the predicted value is binary/categorical we usually refer to the model as a classifier
- If it predicts real values we refer to it as regression

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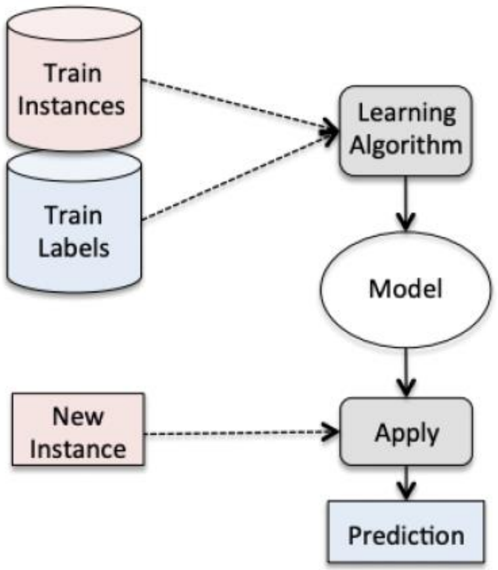
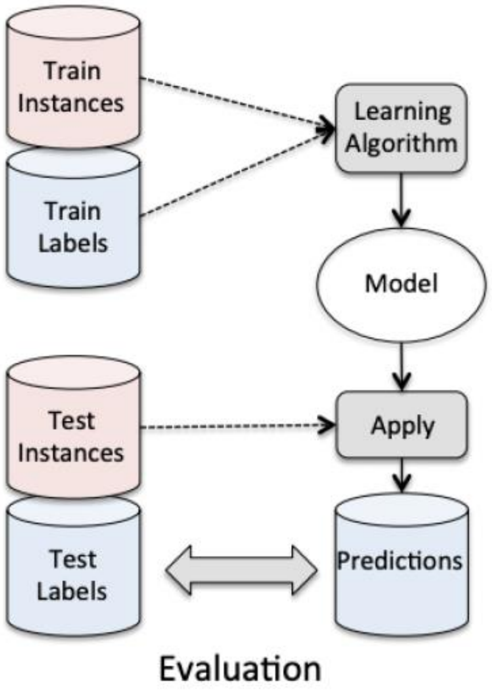
Instance	X1 = length	X2 = width	X3 = colour	Y = class
	55	51	blue	bass
	65	23	pink	tuna
	67	54	blue	bass
	54	20	light-blue	tuna
	62	26	pink	tuna
	44	62	blue	bass
	47	55	light-blue	bass
	73	31	pink	tuna
	54	48	light-blue	bass
	57	23	light-blue	tuna

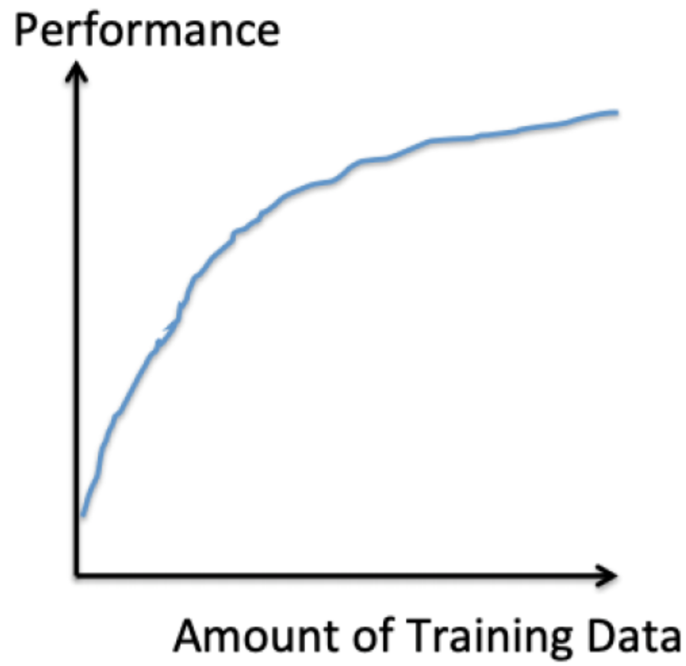

Train Instances
Train Labels
Learning Algorithm
Model
New Instance
Apply
Prediction

How can we decide which model is better?



Generally:

- The more training data the better the test performance



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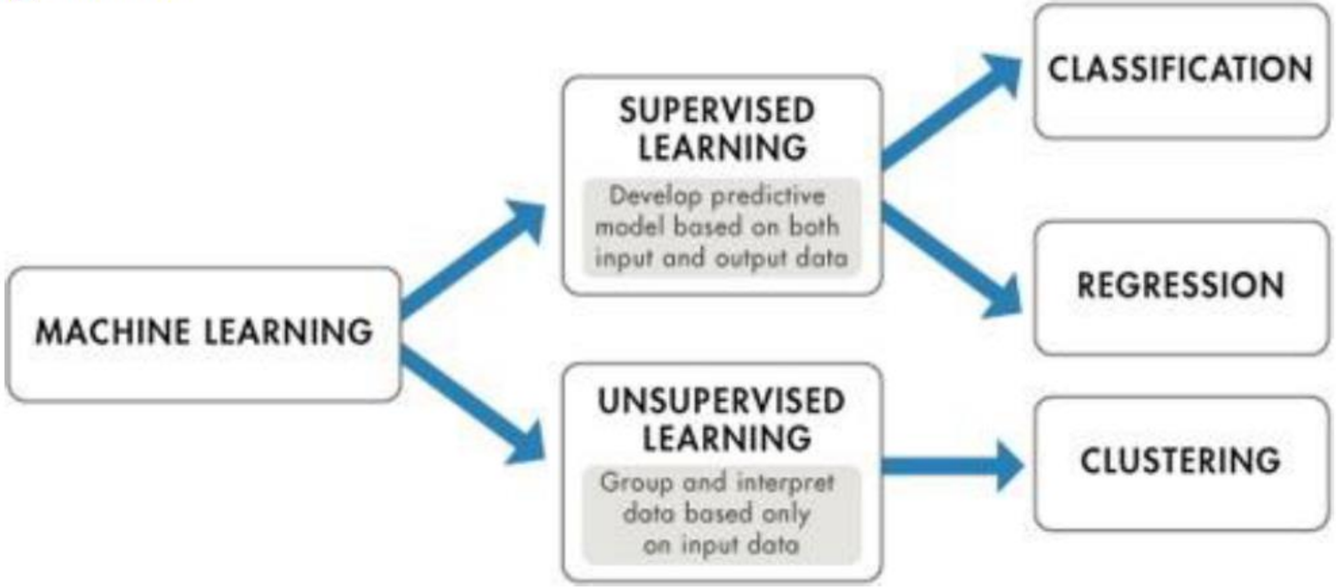
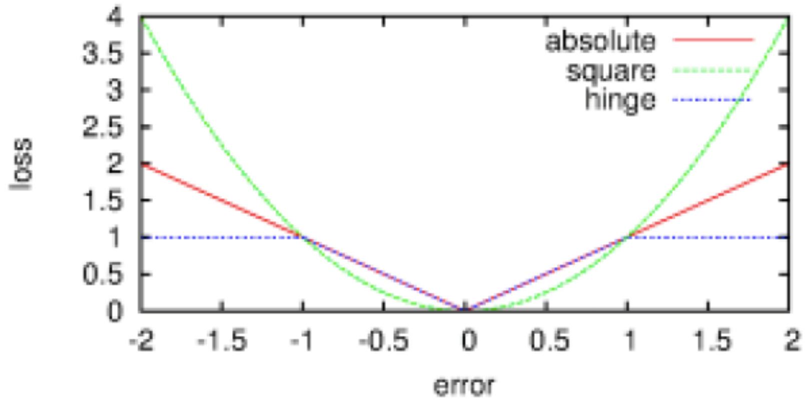
Brownlee, J. (2019). Supervised and Unsupervised Machine Learning Algorithms



Quality is a Function of Error



Error measures the distance between the prediction and the actual value

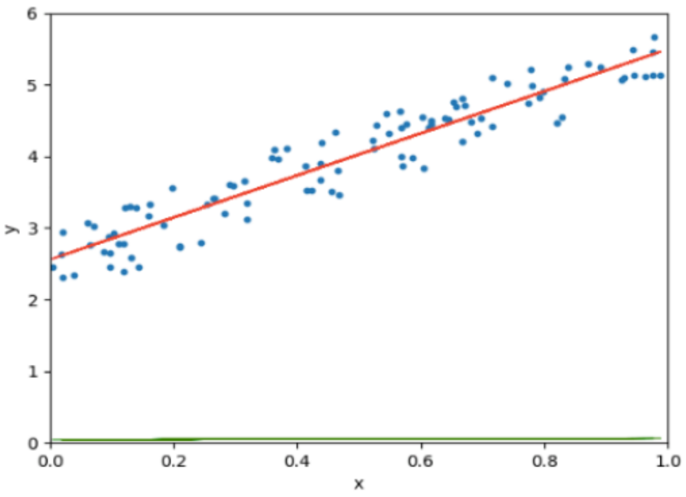
- “0” means no error, prediction was exactly right
- We can convert error to a measure of quality using a loss function, e.g.:

absolute-error(x) = |x|
square-error(x) = x ∗ x
hinge-error(x) = |x| if |x| ≤ 1
1 otherwise

Regression fits a very simple equation to the data:

$$\hat{y}(x; \vec{a}) = a_0 + a_1 x$$

- Data is shown with blue dots, red line is the "linear fitted model"



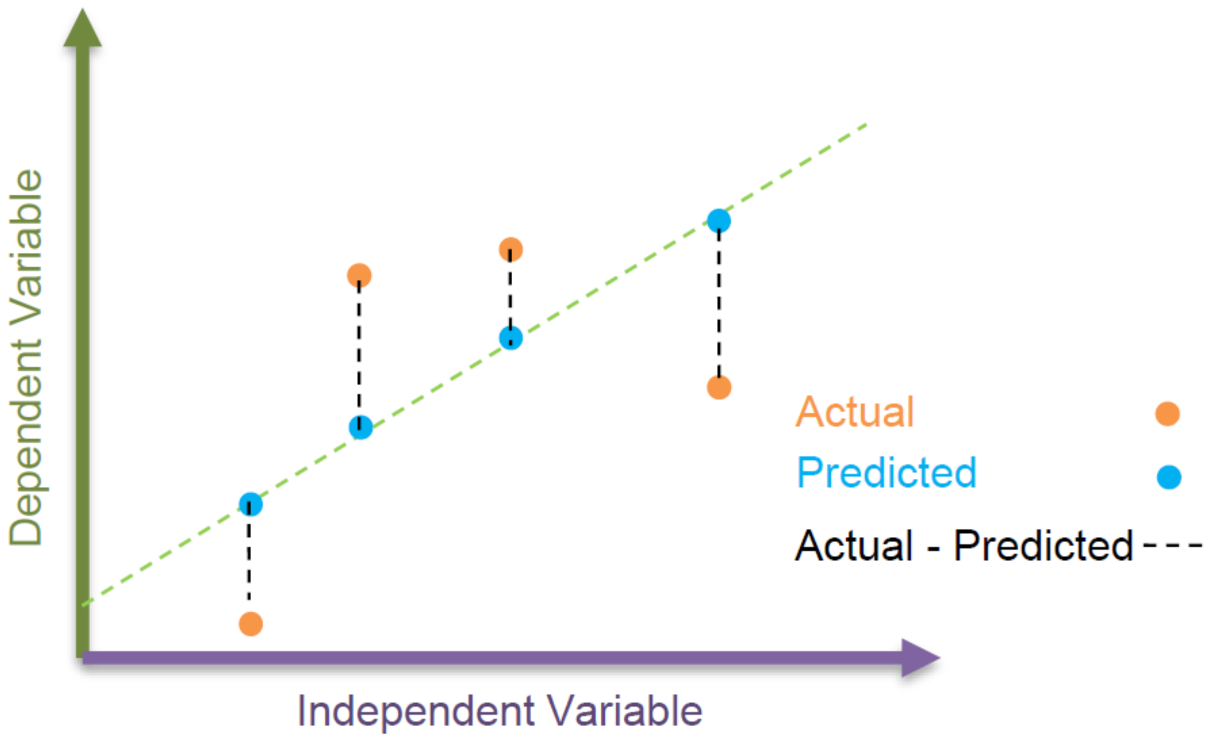
- Here $\hat{y}(x; \vec{a})$ is the for prediction for y at the point x using the model parameters $\vec{a}$ = (a_0, a_1), i.e. the intercept and slope terms.
- Given some data pairs (x_1, y_1), ...,(x_N, y_N), we fit a model by finding the vector $\vec{a}$ that minimises the loss function:

$$\text{mean square error} = MSE_{train} = \frac{1}{N}\sum_{i=1}^{N}\left(\hat{y}(x_i; \vec{a}) - y_i\right)^2$$

- Polynomial regression uses the same linear regression infrastructure to fit a higher order polynomial.
  In this case we fit a 10-th order polynomial:

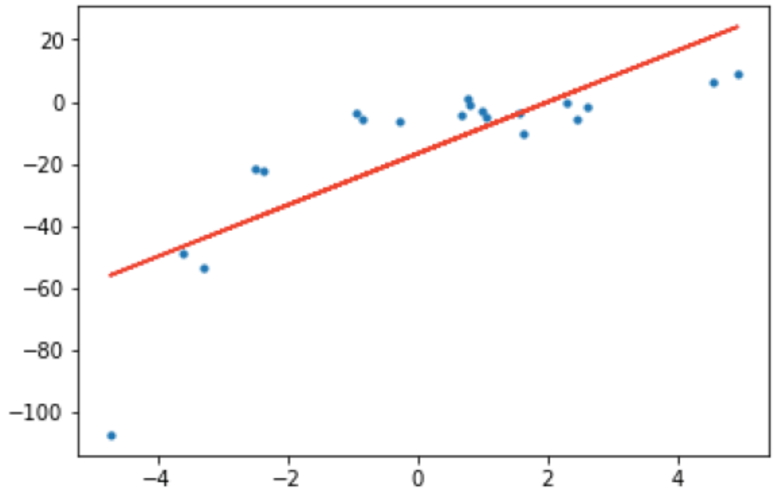
$$\hat{y}(x;\vec{a}) = a_0 + a_1 x + a_2 x^2 + ... a_9 x^9 + a_{10} x^{10} = \sum_{i=0}^{10} a_i x^i$$

Best Fitting Line

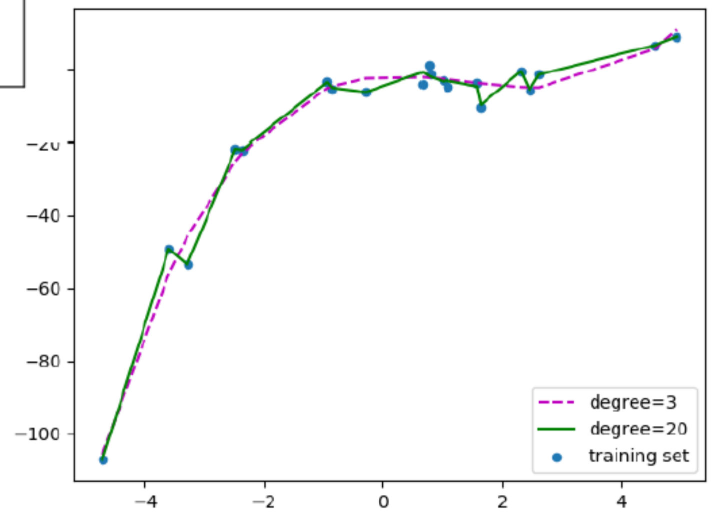


Aim is that the predicted response, be as close as possible to the actual response.

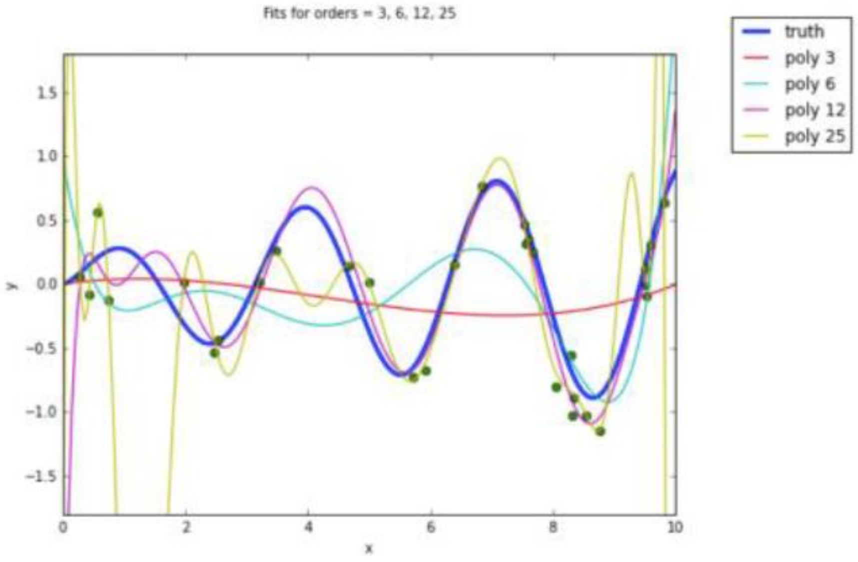
Underfitting and Overfitting



Under-Fitting



Overfitting



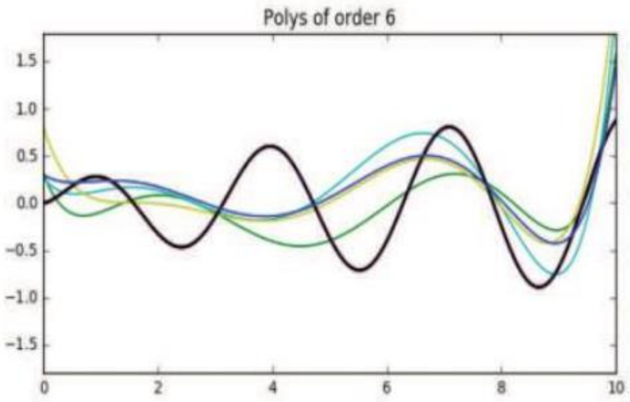
The more parameters a model has, the more complicated a curve it can fit.

- If we don't have very much data and we try to fit a complicated model to it, the model will make wild predictions.
- This phenomenon is referred to as overfitting

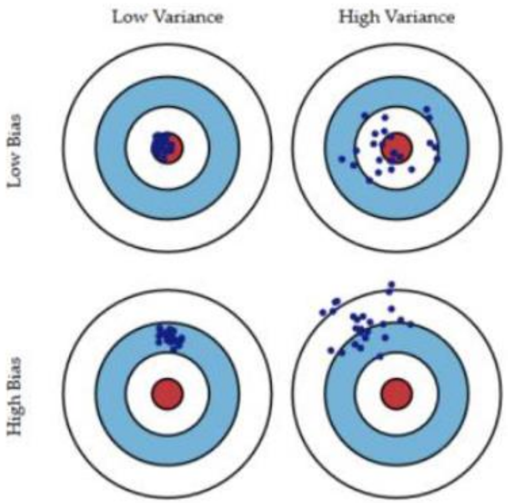
Training Set and Test Set

- Split up the data we have into two non-overlapping parts, a training set and a test set
- Do your learning, run your algorithm, build your model using the training set
- Run evaluation using the test set
- Don’t run evaluation on the training set
- How big to make the test set?

Bias and Variance

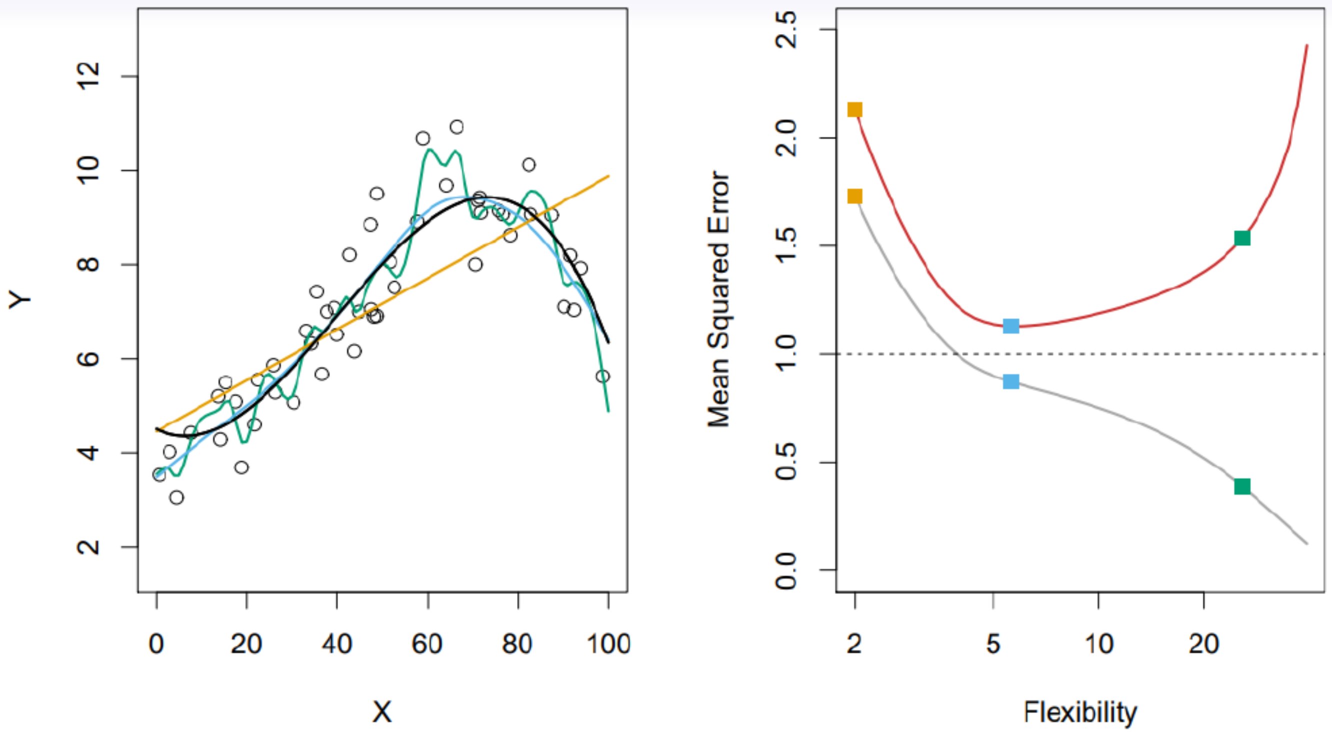


Different data sets of size 30.

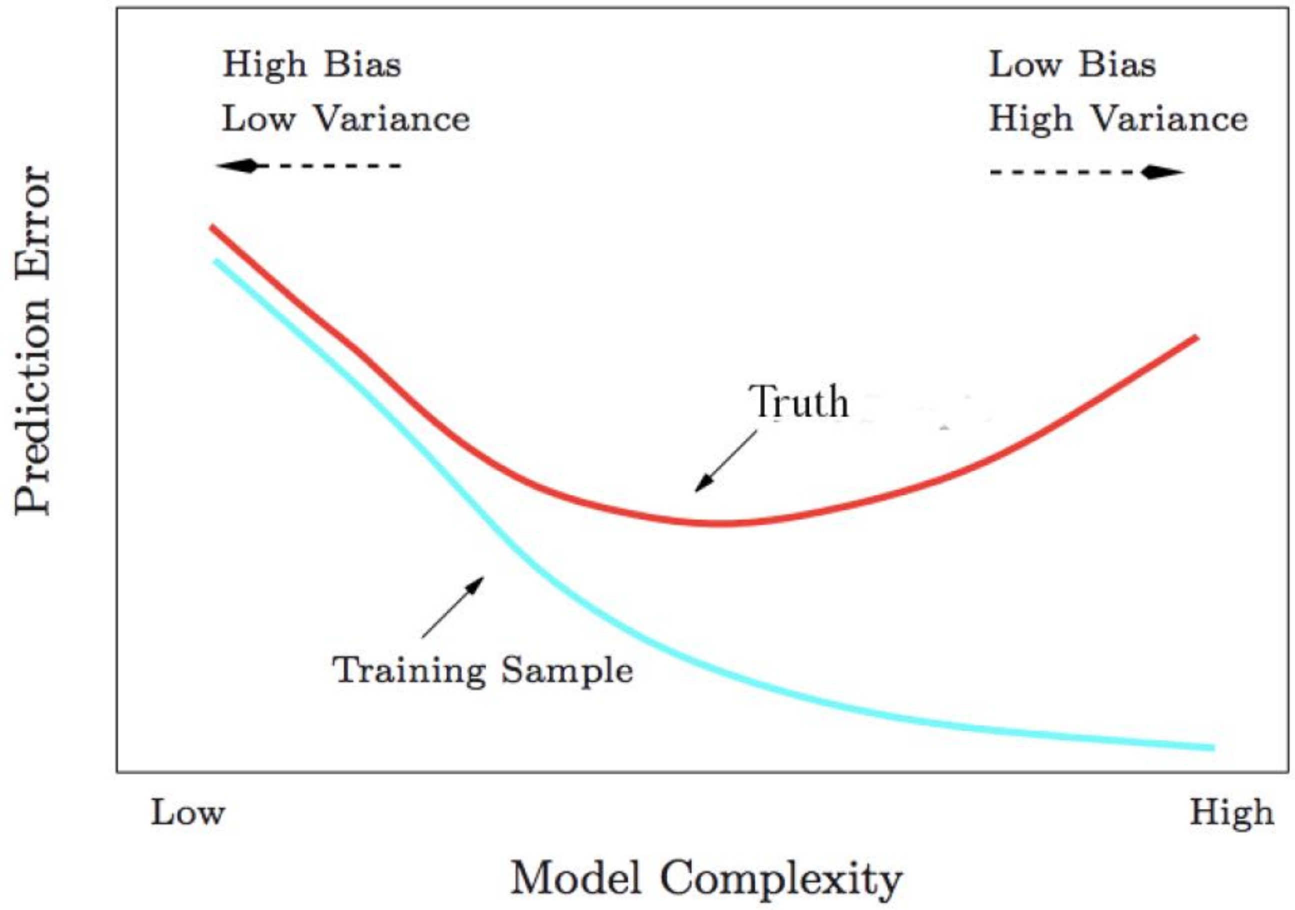


Bias vs Variance Trade-off

Scenario 1



Bias-Variance Tradeoff



Ensembles

- given only data, we do not know the truth and can only estimate what may be the "truth"
- an ensemble is a collection of possible/reasonable models
- often we average the predictions over the models in an ensemble to improve performance $\hat{y}(x) = \frac{1}{M}\sum_{i=1}^{M} \hat{y}^{(i)}(x)$

Classification

Confusion Matrix

- A tool to measure performance for classification

Is accuracy enough?

		Predicted Values	
		Positive(1)	Negative(0)
Actual Values	Positive(1)	True Positive (TP)	False Negative (FN)
	Negative(0)	False Positive (FP)	True Negative (TN)

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		Predicted Class		
		Positive	**Negative**	
Actual Class	**Positive**	True Positive (TP)	False Negative (FN) **Type II Error**	**Sensitivity** $\frac{TP}{(TP + FN)}$
	Negative	False Positive (FP) **Type I Error**	True Negative (TN)	**Specificity** $\frac{TN}{(TN + FP)}$
		Precision $\frac{TP}{(TP + FP)}$	**Negative Predictive Value** $\frac{TN}{(TN + FN)}$	**Accuracy** $\frac{TP + TN}{(TP + TN + FP + FN)}$

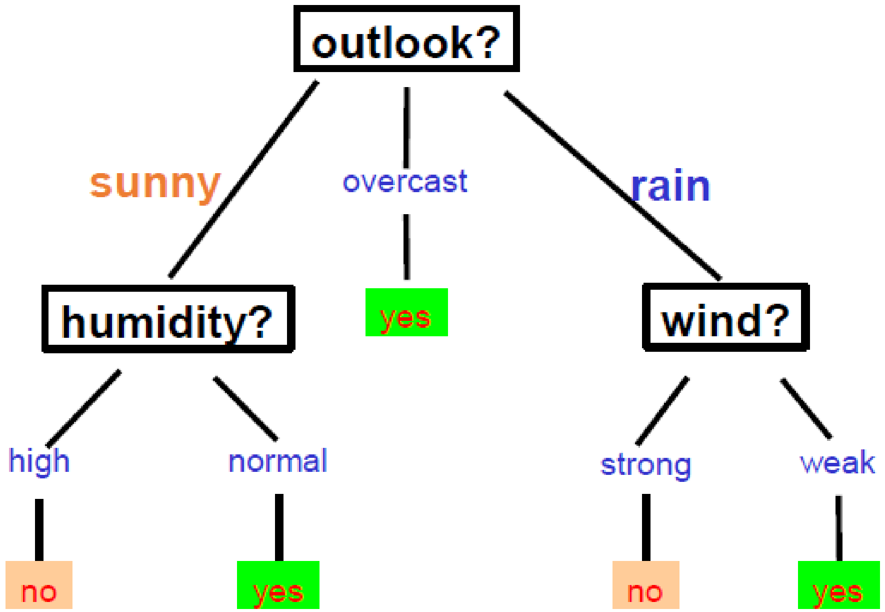
Decision Trees and Regression Trees

What is Decision Trees?

- Predict binary (or categorical)outcomes

What is Regression Trees?

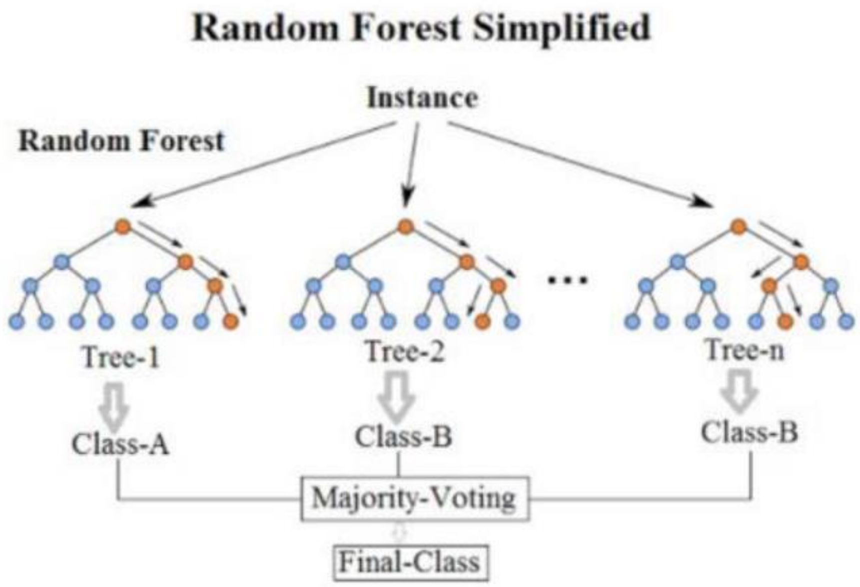
- Predict continuous (i.e. real) values


outlook?
sunny
overcast
rain
humidity?
yes
wind?
high
normal
strong
weak
no
yes
no
yes

- Algorithms for building Decision & Regression trees differ on the criteria (e.g., Entropy) used to:
  - Decide on which feature to split on in each iteration
  - Decide when to stop splitting

What is Random Forest?

- Ensemble learning method that operate by constructing a number of decision trees



What is Clustering?

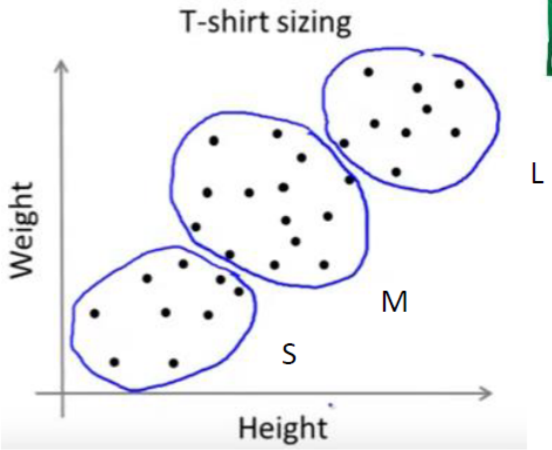
From lecture notes by Andrew Ng

- Grouping a set of data points into different <u>subgroups</u> based on their similarity

called clusters

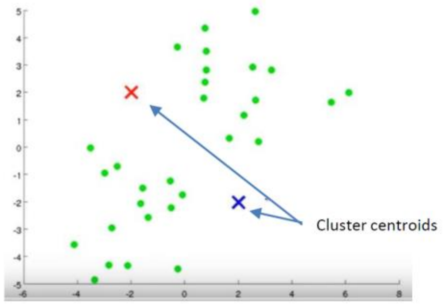
- K-means

- T-shirt manufacturer
- Group into 3 sizes: Small, Medium and Large

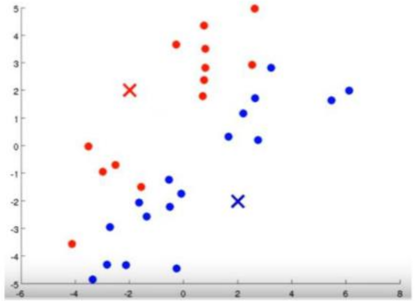


K means

➢ Randomly initialize two points



1. Cluster assignment
2. Move centroid



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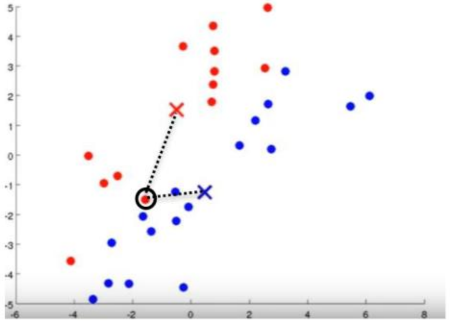

1. Cluster assignment
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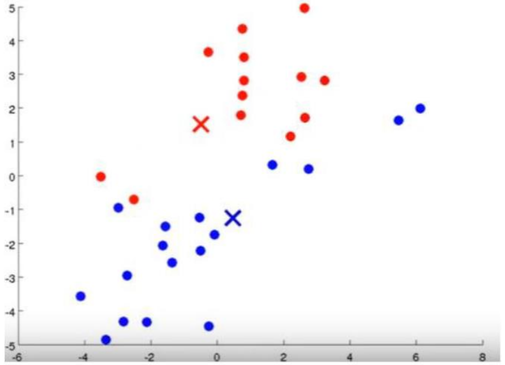
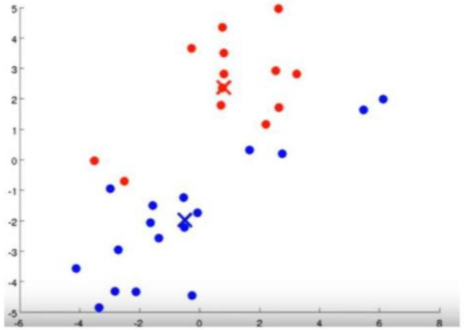


Iterate until there is no changes

1. Cluster assignment
2. Move centroid



1. Cluster assignment
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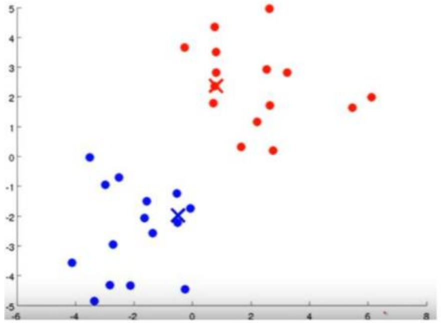
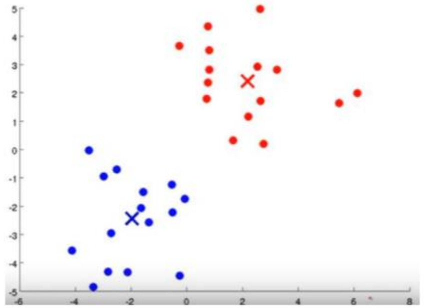


1. Cluster assignment
2. Move centroid



K means is sensitive to initialization !

You have to design the value of K