Dealing with missing values

Handling missing values

- Deletion
  - Delete the rows or columns with missing value
- Imputation
  - Replace cells containing missing values with something meaningful
- Imputation is good. But we cannot always impute
  - MNAR data should never be imputed

Types of Missing values

- Missing completely at random (MCAR)
- Missing at Random (MAR)
- Missing not at Random (MNAR)

	Observed data	Unobserved data	Examples
MCAR	No relation	No relation	A random student's answer sheet is missing. Every answer sheet has equal probability of missing
MAR	Related	No relation	A student's answer sheet missing because he was absent
MNAR	No relation	Related	A student did not answer a question because he did not that study that part

- Simple
- Reduces sample size
- Less degrees of freedom
- Information loss

Handling missing values

- Maintains sample size
- Introduces Bias

Deletion

Imputation

Delete rows

Delete columns

Simple (Univariate)

Multivariate

Non-IID data

IID data

IID data

- Imputation only for MCAR/MAR data
- MNAR data has to be deleted

Forward/ backward filling

Linear interpolation

Constant

Mean Median Mode

Grouped Mean

kNN

Iterative

MICE

Perils of constant imputation

THE WEEK

POLITICS CULTURE BUSINESS PERSONAL FINANCE CARTOONS MORE

FEATURE

How an internet mapping glitch turned this Kansas farm into digital hell

For a decade, the owners of a Kansas farm have been inundated with accusations that they are online scammers and identity thieves

- Better to create a unknown unmapped feature to investigate separately

Mean Imputation

Price
100
90
50
40
20
100
60
120
200

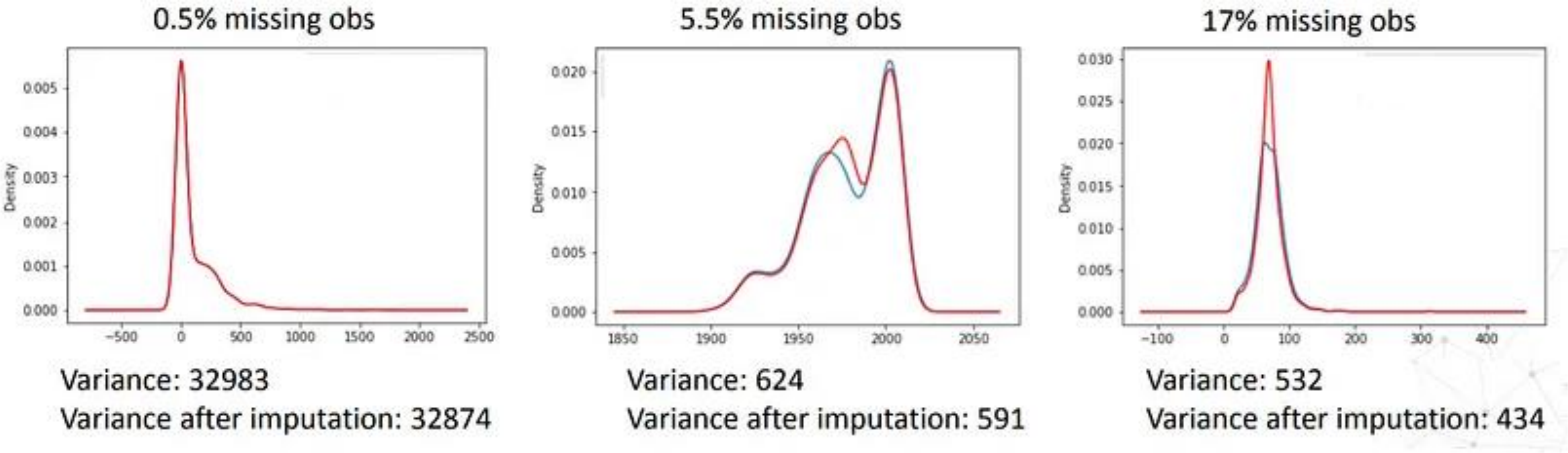
Mean = 86.66

Median = 90

Price
100
90
50
40
20
100
86.66
60
120
86.66
200

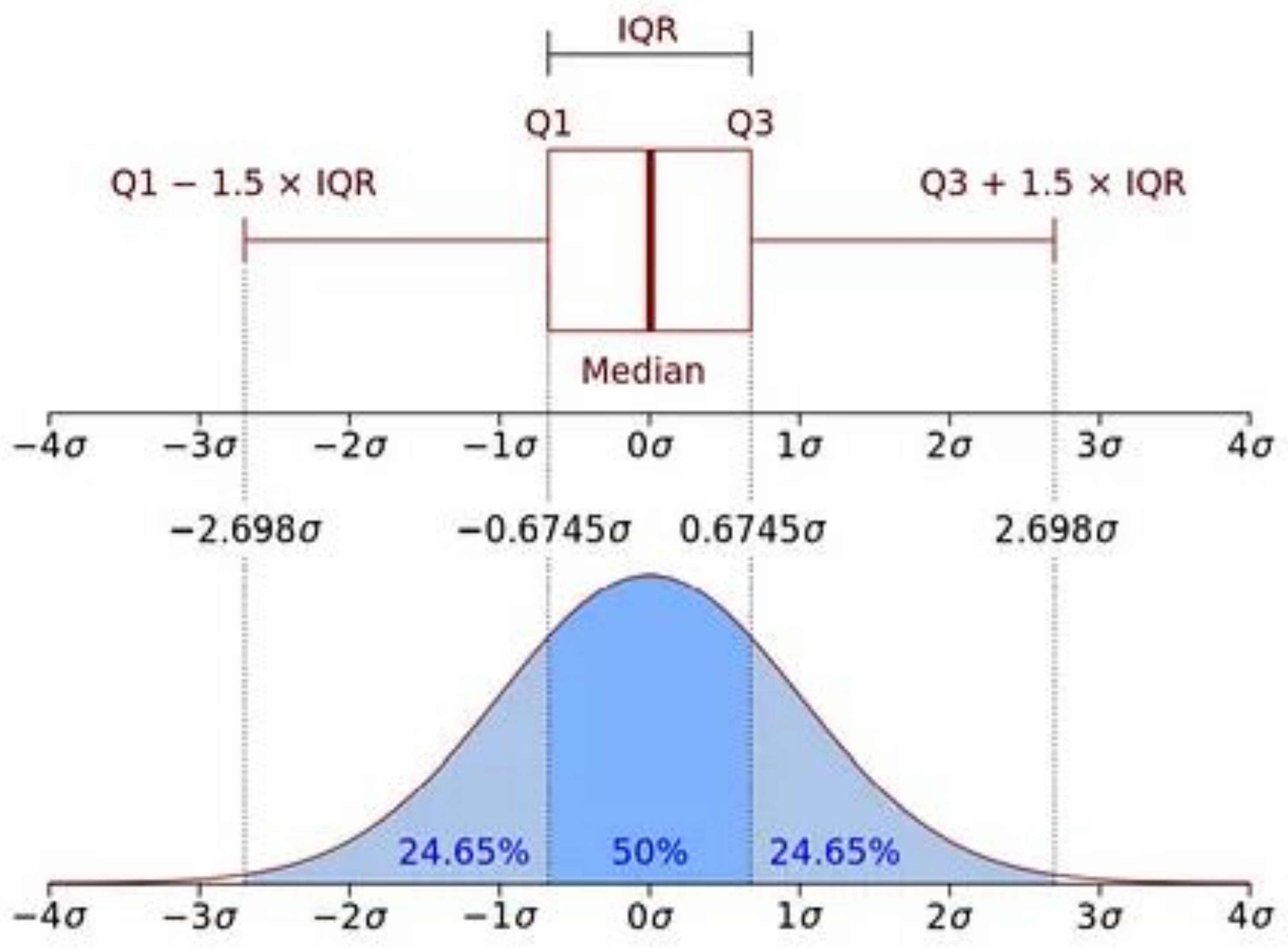
- Assumptions:
- Data is MCAR
- Missing data is mostly same as the rest

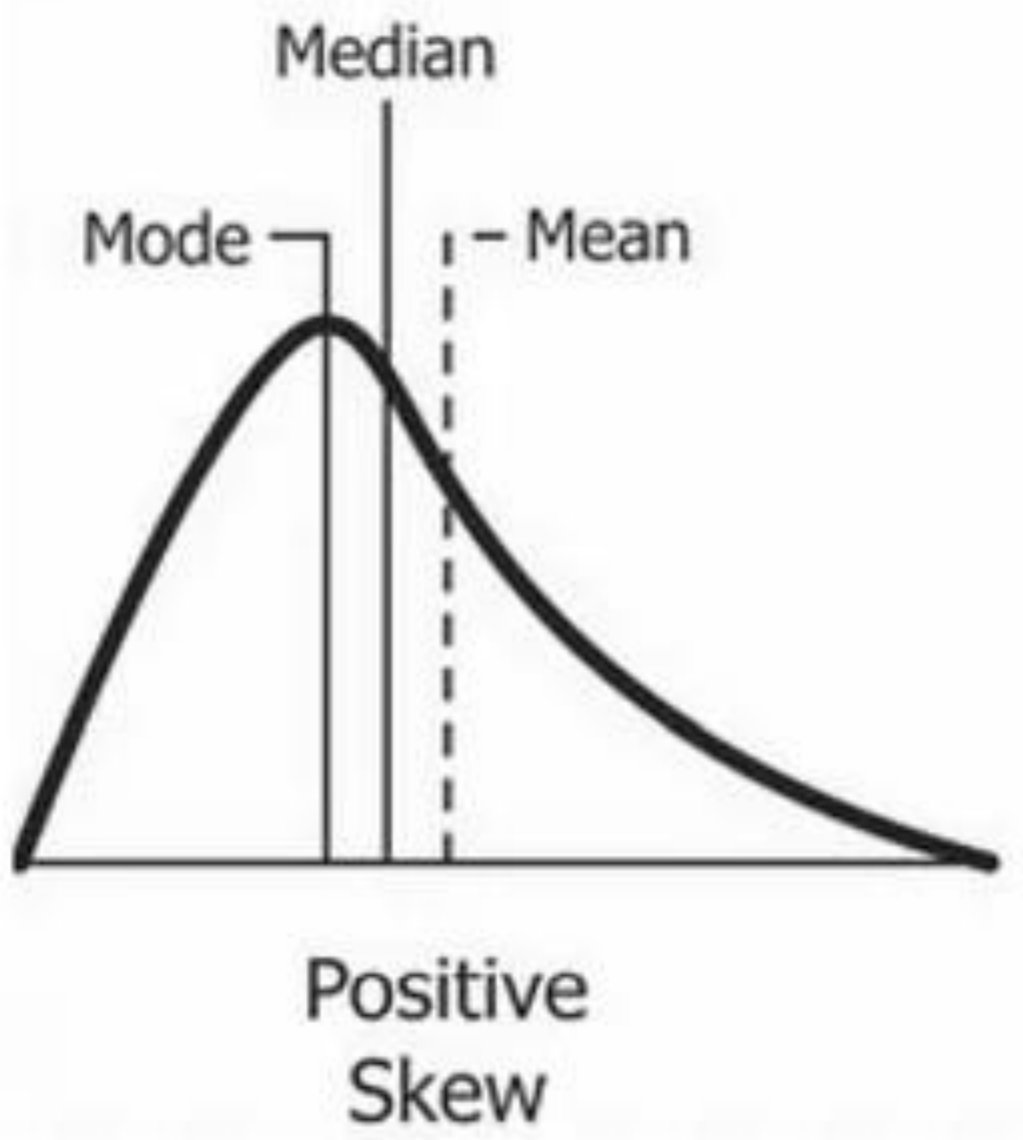
Impact of imputation on variance



- Variance decreases why?

Mean/Median Imputation When?





- If a feature is normally distributed, both mean & median imputation are equal
- If a feature is skewed or has many outliers, then median is better

Grouped Mean imputation

sepal length	sepal width	target
5.1	3.4	0
5.5	4.2	0
5.5	Nan	1
5.1	Nan	0
6.6	3.0	1
6.7	Nan	2
6.2	3.4	2

- Sepal width mean = 3.0
- Setosa Sepal width mean = 2.7
- Virginica Sepal width mean = 3.2
- Solution:
- Impute with grouped mean

Imputation using kNN

kNN for Imputation

HR	BP	Temp
76.0	126.0	38.0
74.0	120.0	NaN
72.0	118.0	37.5
NaN	136.0	37.0
77.0	NaN	39.0

- Logic: Nearest points share similar data
- kNN Imputation working summary:
- Choose k=3
- Find Euclidean distance between
  - Highlighted row & other rows
- Sort distance like kNN
- Pick the top 3 and average

Catch: Regular Euclidean distance wont work due to Nan

Nan Euclidean distance

- Distance between points (3, Nan, 5) & (1,0,0)

$$\sqrt{\frac{3}{2}\{(3-1)^2+(5-0)^2\}} = 6.595453$$

$$d_{xy} = \sqrt{weight \ * squared\ distance\ from\ present\ coordinates}$$

$$weight = \frac{Total\ number\ of\ coordinates}{Number\ of\ present\ coordinates}$$

scikit-learn.org/stable/modules/generated/sklearn.metrics.pairwise.nan_euclidean_distances.html

Distance between (100, Nan, 0.1) & (110, 0.3, 0.2)

All features should be on same scale before KNN imputation

kNN Imputation with k=2

HR	BP	Temp
76.0	126.0	38.0
74.0	120.0	NaN
72.0	118.0	37.5
NaN	136.0	37.0
77.0	NaN	39.0

HR imputation for highlighted record with Nan adjusted distance

$$\sqrt{\frac{2}{2} \times \{(136-126)^2 + (37-38)^2\}}$$

$$\sqrt{\frac{2}{1} \times \{(136-120)^2\}}$$

$$\sqrt{\frac{2}{2} \times \{(136-118)^2 + (37-37.5)^2\}}$$

$$\sqrt{\frac{2}{1} \times \{(37-39)^2\}}$$

- Sort asc & pick top 2
- Average

kNN imputation considerations

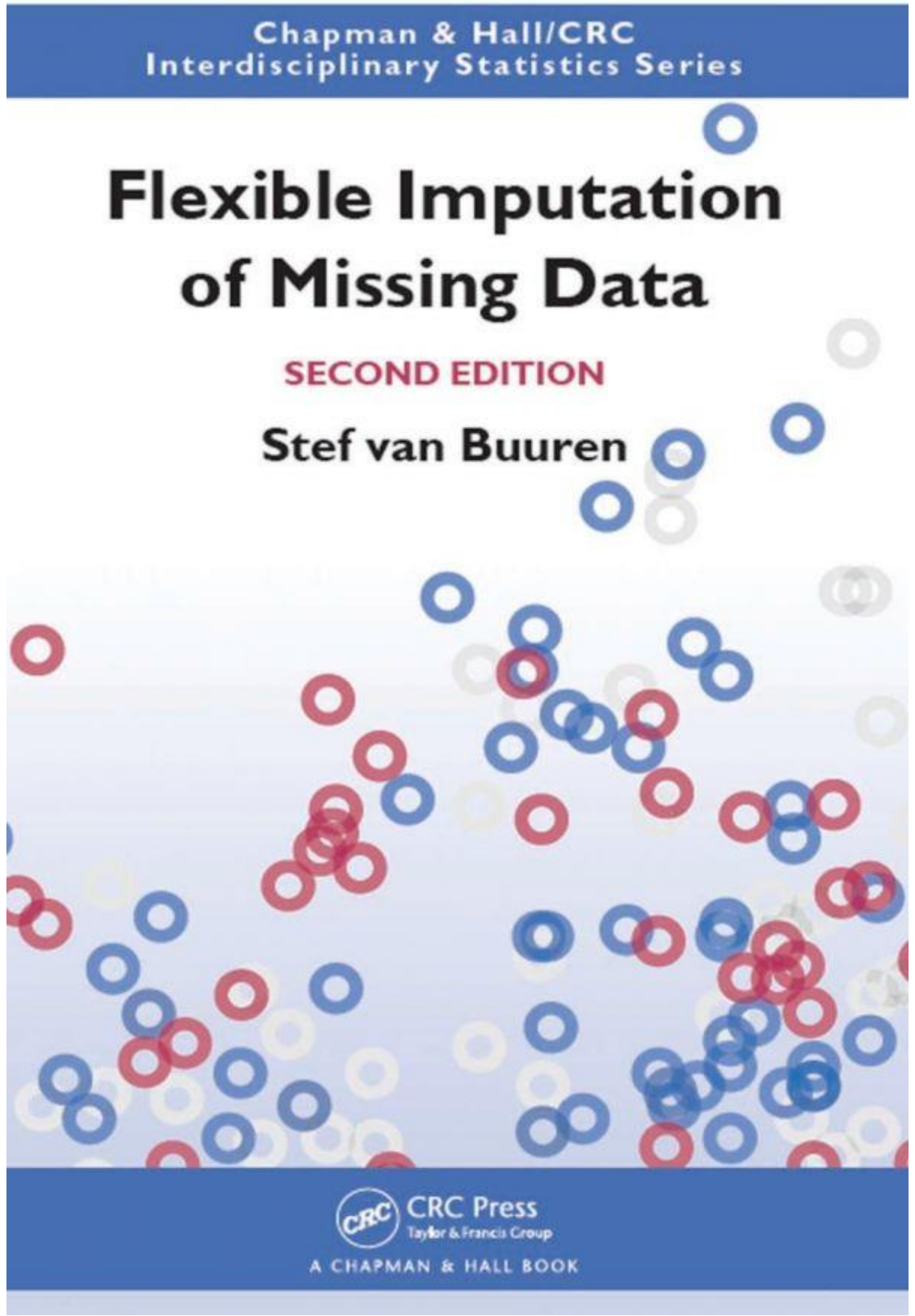
- If kNN is used for imputation, don't use kNN for classification/regression
  - E.g. Choose RandomForest Regressor for prediction
- Choosing k value for imputation is a part of cross validation

```
imputer = KNNImputer(n_neighbors=2, weights='uniform', metric='nan_euclidean')
imputer.fit_transform(df)
```

Iterative Imputation

Missing Data: The missing parts

- Imputation covered in future classes
  - Iterative Imputation,
  - MICE, MissForest
- Markov Chain Monte Carlo methods (will not be covered)



Categorical Variable encoding & imputation

	has heart disease?	resting heart rate (bpm)	pain?	job	medicines	age	family income (USD)
1	no	55	no	nurse	pain	40s	133000
2	no	71	no	admin	beta blockers, pain	20s	34000
3	yes	89	yes	nurse	beta blockers	50s	40000
4	no	67	no	doctor	none	50s	120000

	has heart disease?	resting heart rate (bpm)	pain?	job	medicines	age	family income (USD)
1	no	55	no	nurse	pain	40s	133000
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3	yes	89	yes	nurse	beta blockers	50s	40000
4	no	67	no	doctor	none	50s	120000

	has heart disease?
1	no
2	no
3	yes
4	no

$$\{\text{‘yes’}, \text{‘no’}\} \leftrightarrow \{+1, -1\}$$

1	-1
2	-1
3	+1
4	-1

Can be mapped to 0 and 1

Depends on Algorithm

1. **-1, +1 – Perceptron, SVM**
2. **0, 1 Logistic Regression**

	resting heart rate (bpm)	pain?	job	medicines	age	family income (USD)
1	55	no	nurse	pain	40s	133000
2	71	no	admin	beta blockers, pain	20s	34000
3	89	yes	nurse	beta blockers	50s	40000
4	67	no	doctor	none	50s	120000

pain?
0
0
1
0

job
nurse
admin
nurse
doctor

- Ordinal Encoding - 1, 2, 3, 4
- Is admin > nurse and doctor
- Is it a linear scale?

- Binary code - 00, 01, 10, 11
- Inadvertently introduced pattern in job

nurse	0	0	0
admin	0	0	1
pharmacist	0	1	0
doctor	0	1	1
social worker	1	0	0

job
nurse
admin
nurse
doctor

- Turn each category into 0/1
- One hot encode – 0001 0010 0100 1000
- No pattern, feature explosion
- Not good for high cardinality

nurse	1	0	0	0	0
admin	0	1	0	0	0
pharmacist	0	0	1	0	0
doctor	0	0	0	1	0
social worker	0	0	0	0	1

medicines
pain
beta blockers, pain
beta blockers
none

- Should we use one hot encoding?

pain	1	0	0	0
pain & beta blockers	0	1	0	0
beta blockers	0	0	1	0
no medications	0	0	0	1

- How about Factored encoding?

pain	1	0
pain & beta blockers	1	1
beta blockers	0	1
no medications	0	0

- How is it different from binary encoding?

age
40s
20s
50s
50s

age
45
25
55
55

decade
4
2
5
5

Reminds of IP Address Geo location fiasco

Encode Ordinal Data

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

- Log Levels
  - Trace, Debug, Info, Warn, Error, Fatal
  - Do these map to 1,2,3,4,56?
  - Or 1,2,5,8,10?

Imputing Categorical Variables

- Cannot do mean/median
- Impute the most frequent value
- Grouped mode
- Impute the value to be a new category

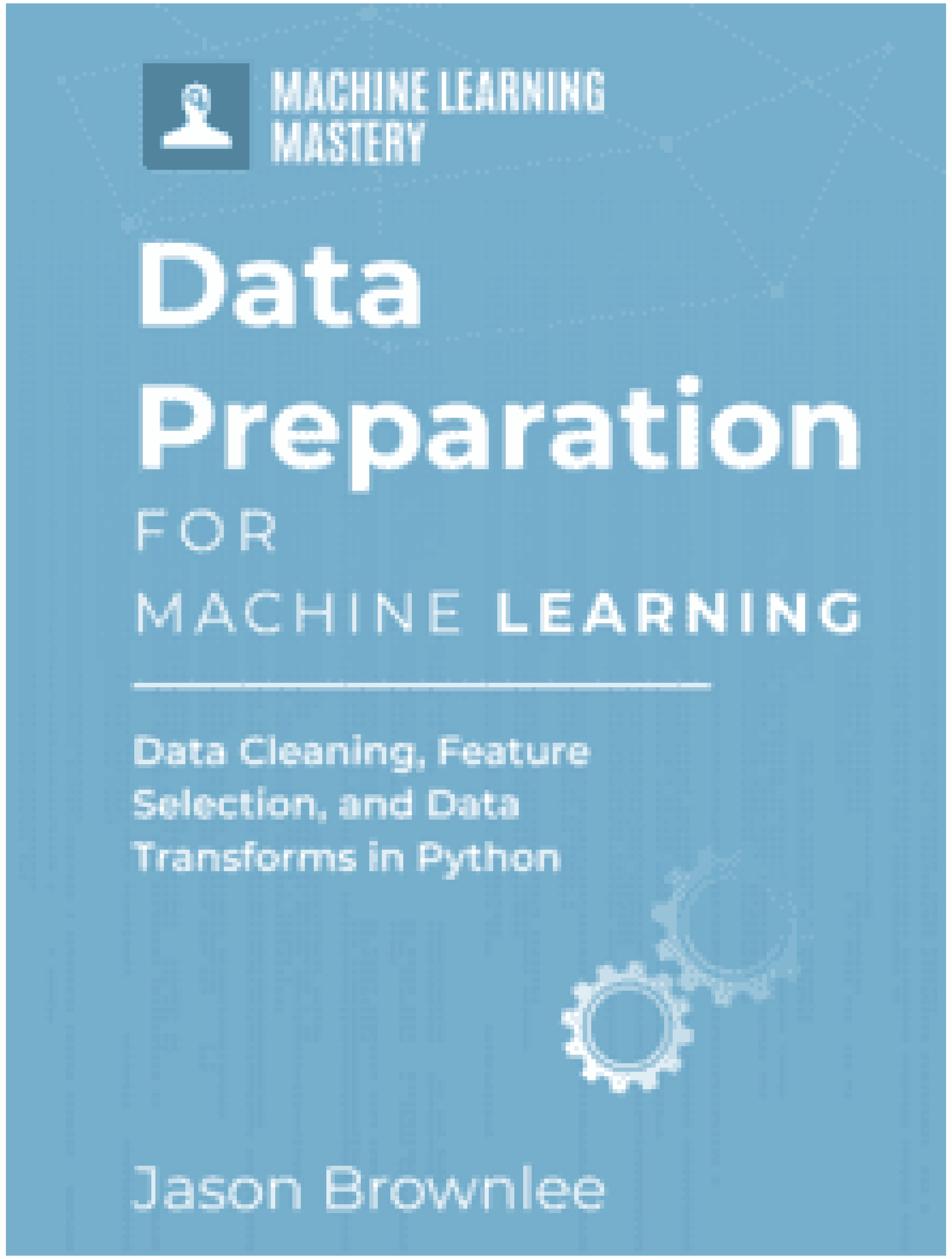
Recap

- kNN Regression
- Data imputation
  - Univariate – Mean, Median, Mode, Grouped Mean
  - Multivariate – kNN (Nan Euclidean distance)
- Encoding transformations for categorical variables
  - Ordinal, Factored, One hot, binary,
- Problem: Imputation first or standardization first?

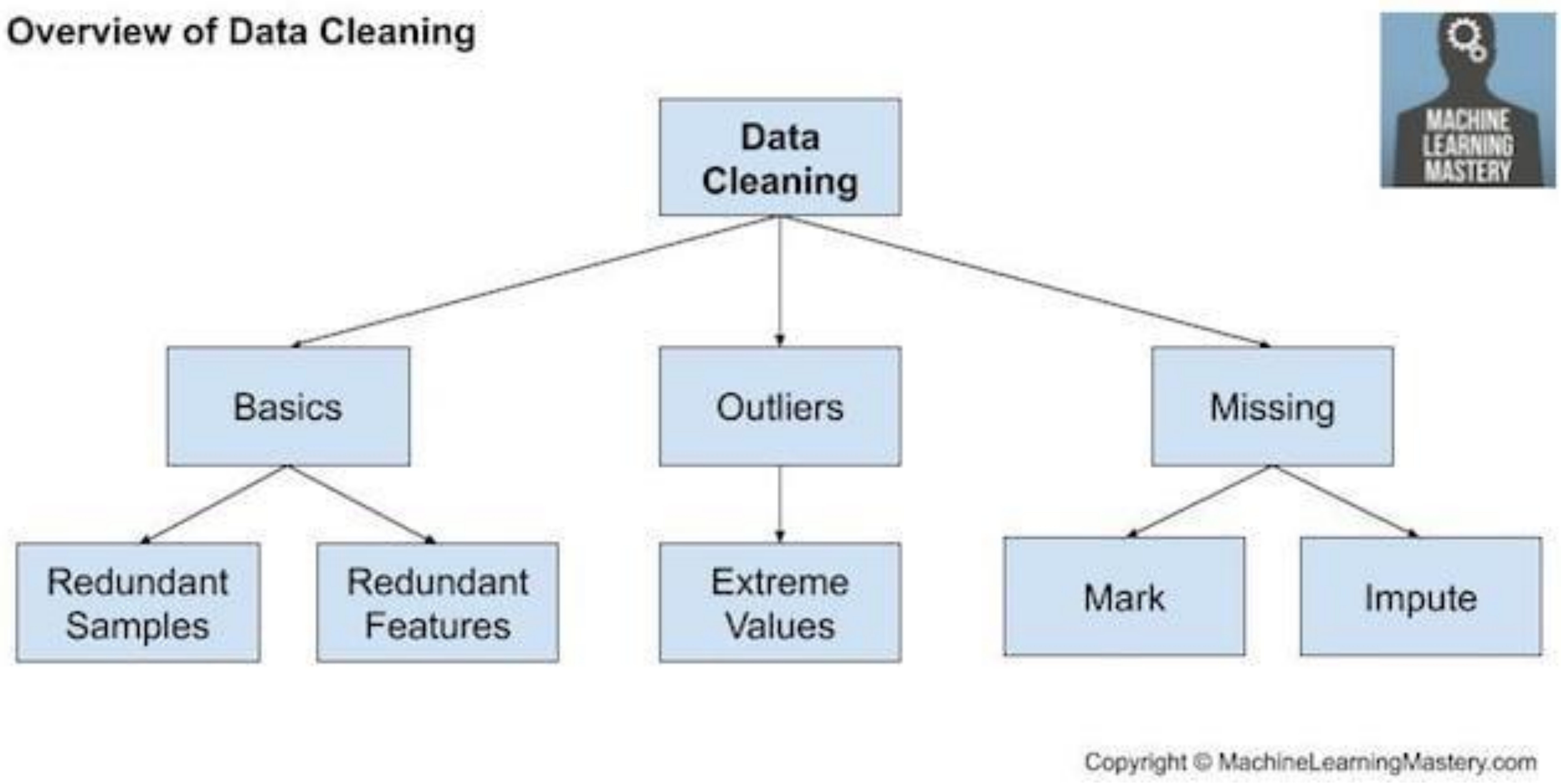
Solutions: No one right answer

- Some have opined standardize first
- Others: impute with a temporary value first
- Hybrid solution approach (one variation):
  - Grouped mean impute + missing indicator (adds 0/1)
  - Standardize
  - Set Nan again using Missing Indicator, then KNN Impute
- Can use missing indicator as feature for ML prediction

Data cleaning, Feature Engineering books



Data cleaning: Big picture




QUESTIONS

Literature Survey