

Machine Learning for Finance

Prepared by Dr. Diaa Salama

FNT633
Data Preprocessing

Lecture 3





مجموعة جامعة
الجميع الذكية
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Machine Learning for Finance

Lecture 3

FNT633
Data Preprocessing

Prepared by
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- Supervised learning KNN
- Data Preparation (Preprocessing)

K-Nearest Neighbor Classification

K-NN

- Used for
 - Classification
 - Regression

- Used for
 - Classification
 - Regression

K-Nearest Neighbor Classification

- K nearest neighbors measured by a distance function.
- These functions are valid only with continuous variables.

Euclidean

$$\sqrt{\sum_{i=1}^k (x_i - y_i)^2}$$

Manhattan

$$\sum_{i=1}^k |x_i - y_i|$$

Minkowski

$$\left(\sum_{i=1}^k (|x_i - y_i|)^q \right)^{1/q}$$

KNN Example

- Consider the following data concerning credit default. Age and Loan are two numerical variables (predictors) and Default is the target.

Age	Loan	Default
25	\$40,000	N
35	\$60,000	N
45	\$80,000	N
20	\$20,000	N
35	\$120,000	N
52	\$18,000	N
23	\$95,000	Y
40	\$62,000	Y
60	\$100,000	Y
48	\$220,000	Y
33	\$150,000	Y

- Know we want to classify unknown case ((Age=48 and Loan=\$142,000) using Euclidean distance.)

!!!!

- Using Euclidean distance: E.g. distance between (48, \$142k) and (33, 150k)
- □ $\text{Sqrt}[(48-33)^2 + (142000-150000)^2] = 8000.01$
- So for all the dataset

Age	Loan	Default	Distance	
25	\$40,000	N	102000	
35	\$60,000	N	82000	
45	\$80,000	N	62000	
20	\$20,000	N	122000	
35	\$120,000	N	22000	2
52	\$18,000	N	124000	
23	\$95,000	Y	47000	
40	\$62,000	Y	80000	
60	\$100,000	Y	42000	3
48	\$220,000	Y	78000	
33	\$150,000	Y	8000	1
48	\$142,000	?		

Euclidean Distance

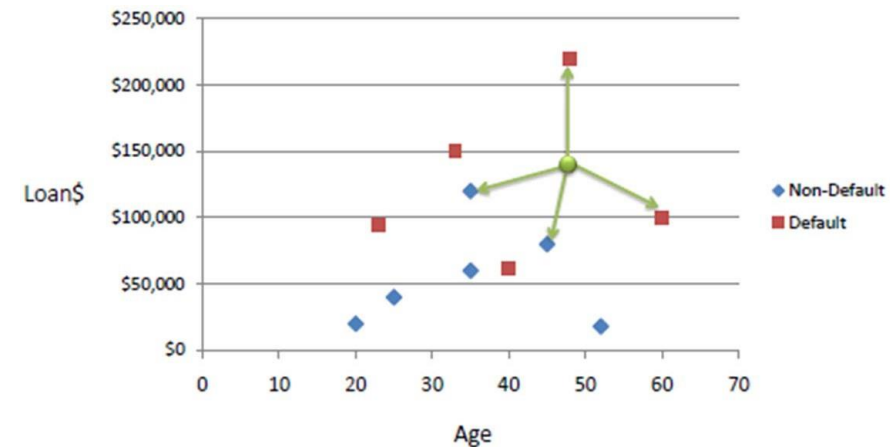
$$D = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2}$$

- Know we choose the number of neighbors K
 - If K=1 then this case is Y
 - If K=3 then we have 2 Y and 1 N which give us Y

Age	Loan	Default	Distance
25	\$40,000	N	102000
35	\$60,000	N	82000
45	\$80,000	N	62000
20	\$20,000	N	122000
35	\$120,000	N	22000
52	\$18,000	N	124000
23	\$95,000	Y	47000
40	\$62,000	Y	80000
60	\$100,000	Y	42000
48	\$220,000	Y	78000
33	\$150,000	Y	8000
48	\$142,000	?	

Euclidean Distance

$$D = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2}$$



1- Classification using KNN:

- Steps:
 - Find distance.
 - Find Rank.
 - Find the output according to the value of k.
- Euclidean Distance:

$$d = \sqrt{(y_2 - y_1)^2 + (x_2 - x_1)^2}$$

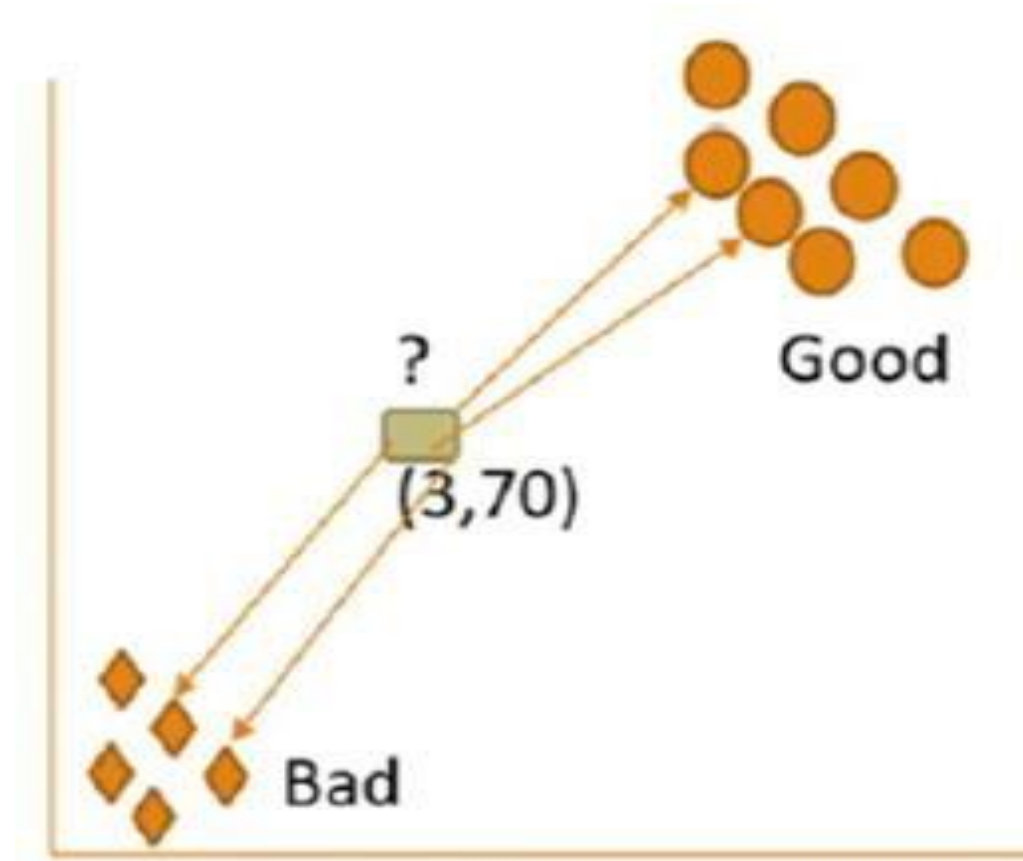
Example

- Consider $k = 3$

Name	Cigarettes	Weight	Heart Attack	Distance	
A	7	70	Bad	$\sqrt{(3-7)^2 + (70-70)^2}$ $= 4$	①
B	7	40	Bad	$\sqrt{(3-7)^2 + (70-40)^2}$ $= 30.27$	④
C	3	40	Good	$\sqrt{(3-3)^2 + (70-40)^2}$ $= 30.00$	②
D	1	40	Good	$\sqrt{(3-1)^2 + (70-40)^2}$ $= 30.07$	③
E	3	70	Good		

Example

- Consider $k = 4$



Example2 :

Height (CM)	Weight (KG)	Class
167	51	Underweight
182	62	Normal
176	69	Normal
173	64	Normal
172	65	Normal
174	56	Underweight
169	58	Normal
173	57	Normal
170	55	Normal
170	57	?

Solution cont.:

Height (CM)	Weight (KG)	Class	Distance	Rank
169	58	Normal	1.4	1
170	55	Normal	2	2
173	57	Normal	3	3
174	56	Underweight	4.1	4
167	51	Underweight	6.7	5
173	64	Normal	7.6	6
172	65	Normal	8.2	7
182	62	Normal	13	8
176	69	Normal	13.4	9
170	57	?		

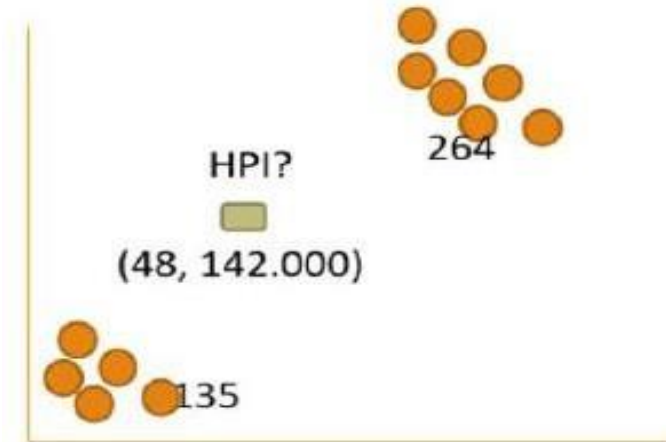
Solution cont.:

Height (CM)	Weight (KG)	Class	Distance	Rank
169	58	Normal	1.4	1
170	55	Normal	2	2
173	57	Normal	3	3
174	56	Underweight	4.1	4
167	51	Underweight	6.7	5
173	64	Normal	7.6	6
172	65	Normal	8.2	7
182	62	Normal	13	8
176	69	Normal	13.4	9
170	57	?		

- If $K=1$, Normal
- If $K=2$, Normal
- If $K=3$, Normal
- If $K=4$, Normal
- If $K=5$, Normal

2- Regression Using KNN:

Age	Loan	House Price Index	Distance
25	\$40,000	135	102000
35	\$60,000	256	82000
45	\$80,000	231	62000
20	\$20,000	267	122000
35	\$120,000	139	22000
52	\$18,000	150	124000
23	\$95,000	127	47000
40	\$62,000	216	80000
60	\$100,000	139	42000
48	\$220,000	250	78000
33	\$150,000	264	8000
48	\$142,000	?	



2- Regression Using KNN:

K=1

- using the training set to classify an unknown case
- (Age=33 and Loan=\$150,000) {Euclidean distance}.
- If K=1 then the nearest neighbor is the last case in the set
- with HPI=264.
- $D = \text{Sqrt}[(48-33)^2 + (142000-150000)^2] = 8000.01$ >> HPI = 264

K=3

- the prediction for HPI is equal to the average of HPI for the top three neighbors
- $\text{HPI} = (264+139+139)/3 = 180.7$

Age	Loan	House Price Index	Distance
25	\$40,000	135	102000
35	\$60,000	256	82000
45	\$80,000	231	62000
20	\$20,000	267	122000
35	\$120,000	139	22000 2
52	\$18,000	150	124000
23	\$95,000	127	47000
40	\$62,000	216	80000
60	\$100,000	139	42000 3
48	\$220,000	250	78000
33	\$150,000	264	8000 1
48	\$142,000	?	

Example: Assume $k = 3$

x1	x2	weight
7	7	6
7	4	3
3	4	2
1	3	1
2	1	?

Solution: $K = 3$

$$\text{Weight} = \frac{3+2+1}{3} = 2$$

x1	x2	weight	Distance	Rank
7	7	6	7.81	4
7	4	3	5.83	3
3	4	2	3.16	2
1	3	1	2.23	1
2	1	2		

KNN disadvantages

- Computationally expensive
- Requires a large memory to store the training data.

Week

04

Data Preparation (Data Preprocessing)

Reasons for Data Cleansing

- The data to be analyzed may be:
 - Incomplete; where the data is missing (empty record)
 - Noisy; where data may contain errors (data that have incorrect values -Gender Z)or outlier values (Outliers are data values that deviate from expected values of the rest of the data set) (Age 2500)
 - Inconsistent; where data may contain discrepancies in the values (age – birthdate) , (Total-price and (unit-price and quantity).

How can Data be Cleaned?

- Filling-in Missing Values
- Smoothing Noisy Data (Validation and correction – Standardization)
- Identifying and Removing Outliers Using Inter-quartile Range
- Resolving Inconsistency (age – birthdate)

Typical Example

Customer ID	Zip	Gender	Income	Age	Marital Status	Transaction Amount
1001	10048	M	75000	C	M	5000
1002	J2S7K7	F	-40000	40	W	4000
1003	90210		10000000	45	S	7000
1004	6269	M	50000	0	S	1000
1005	55101	F	99999	30	D	3000

Sample Table

Typical Example (Incomplete Data)

Customer ID	Zip	Gender	Income	Age	Marital Status	Transaction Amount
1001	10048	M	75000	C	M	5000
1002	J2S7K7	F	-40000	40	W	4000
1003	90210		10000000	45	S	7000
1004	6269	M	50000	0	S	1000
1005	55101	F	99999	30	D	3000

Sample Table

Typical Example (Data Values Errors)

Customer ID	Zip	Gender	Income	Age	Marital Status	Transaction Amount
1001	10048	M	75000	C	M	5000
1002	J2S7K7	F	-40000	40	W	4000
1003	90210		10000000	45	S	7000
1004	6269	M	50000	0	S	1000
1005	55101	F	99999	30	D	3000

Sample Table

■ Reasons:

- The Zip code consists of five digits and cannot contain any letters
- Income must be positive number
- Age must be positive number

Typical Example (Outlier Values)

Customer ID	Zip	Gender	Income	Age	Marital Status	Transaction Amount
1001	10048	M	75000	C	M	5000
1002	J2S7K7	F	-40000	40	W	4000
1003	90210		10000000	45	S	7000
1004	6269	M	50000	0	S	1000
1005	55101	F	99999	30	D	3000

Sample Table

- Reasons:
 - Outliers are data values that deviate from expected values of the rest of the data set
 - The values 10000000 and -40000 look very divergent from the rest of values

Typical Example (Ambiguity)

Customer ID	Zip	Gender	Income	Age	Marital Status	Transaction Amount
1001	10048	M	75000	C	M	5000
1002	J2S7K7	F	-40000	40	W	4000
1003	90210		10000000	45	S	7000
1004	6269	M	50000	0	S	1000
1005	55101	F	99999	30	D	3000

Sample Table

- Reasons:
 - “S” in Marital Status could refer to “Single” or “Separated”
 - So, there is a kind of ambiguity in the data

Reasons for Incomplete Data

- Relevant data may not be recorded because:
 - A misunderstanding from the data entry persons
 - Equipment failure
- Relevant data may not be available because it is unknown or providing it is optional

There are several ways to deal with missing data:

- Replace the missing value with some default value
- Replace the missing value with the field mean for the fields that take numerical values or the mode (if exists) for the fields that take categorical values
- Replace the missing values with a value generated at random from the field distribution observed

Mean, Median, and Mode

- The mean for a population of size n can be computed by:

$$\bar{x} = \frac{1}{n} \cdot \sum_{i=1}^n x_i$$

- Consider the following list of 9 numbers:

13, 15, 12, 17, 22, 11, 13, 19, 12

Mean = **(13 + 15 + 12 + 17 + 22 + 11 + 13 + 19 + 12)/9 = 14.88889**

- The median is the middle value of the ordered list of numbers.

- Consider the following list of 9 numbers:

13, 15, 12, 17, 22, 11, 13, 19, 12

- To compute the median, you need first to order the numbers:

11, 12, 12, 13, 13, 15, 17, 19, 22

- Hence, the median is **13**

- The median is the middle value of the ordered list of numbers.

- Consider the following list of 10 numbers:

13, 15, 12, 17, 22, 11, 13, 19, 12, 14

- To compute the median, you need first to order the numbers:

11, 12, 12, 13, 13, 14, 15, 17, 19, 22

- Hence, the median is $(13 + 14)/2 = 13.5$

- The **mode** of a set of data is the value in the set that **occurs most often**.

- Consider the following list of numbers:

13, 15, 12, 17, 22, 11, 13, 19, 13

Number	Occurrence	Number	Occurrence
13	3	22	1
15	1	11	1
12	1	19	1
17	1		

Mode is **13**

Mean, Median, and Mode

- The **mode** of a set of data is the value in the set that **occurs most often**.

- Consider the following list of numbers:

13, 15, 12, 17, 22, 11, 13, 19, 13

Number	Occurrence	Number	Occurrence
13	3	22	1
15	1	11	1
12	1	19	1
17	1		

Mode is **13**

- The **mode** of a set of data is the value in the set that **occurs most often**.

- Consider the following list of numbers:

13, 15, 12, 17, 22, 11, 13, 19, 12

Number	Occurrence
13	2
15	1
12	2
17	1

Number	Occurrence
22	1
11	1
19	1

Mode is **13** and **12** (Bimodal)

- The **mode** of a set of data is the value in the set that **occurs most often**.

- Consider the following list of numbers:

13, 15, 12, 17, 22, 11, 19

Number	Occurrence	Number	Occurrence
13	1	22	1
15	1	11	1
12	1	19	1
17	1		

There is **no mode**

Handling Missing Values

Field1 (Numeric)	Field2 (Catrgorical)	Field3 (Numeric)	Field4 (Numeric)
21	A	300	67
	A	250	
	B	280	93
24	W		76
22	C	500	85
12		350	66
11		330	
16	A	220	84
16	C		98
17		420	78
18	W	360	89

A set of fields with missing values

Handling Missing Values

Field1 (Numeric)	Field2 (Categorical)	Field3 (Numeric)	Field4 (Numeric)
21	A	300	67
	A	250	
	B	280	93
24	W		76
22	C	500	85
12		350	66
11		330	
16	A	220	84
16	C		98
17		420	78
18	W	360	89

A set of fields with missing values

Handling Missing Values (Using Default Values)

Field1 (Numeric)	Field2 (Catrgorical)	Field3 (Numeric)	Field4 (Numeric)
21	A	300	67
0	A	250	50
0	B	280	93
24	W	240	76
22	C	500	85
12	N	350	66
11	N	330	50
16	A	220	84
16	C	240	98
17	N	420	78
18	W	360	89

Defaults

- Field1 Default: 0
- Field3 Default: 240

Field2 Default: N
Field4 Default: 50

Handling Missing Values (Using Means and Modes)

- Use the mean for the numeric fields and the mode (if exists) for the categorical fields
- If mode doesn't exist, you need to rely on either a default value or to use a random value
- Numeric Fields: Field1, Field3, and Field4
- Field1 Mean = $(21+24+22+12+11+16+16+17+18)/9 = 17.44$
- Field3 Mean = 334.44
- Field4 mean = 81.78
- If any field doesn't accept decimal values, just approximate the mean value

- Field2 is categorical, hence we need to compute the mode from the existing values

Category	Occurrence
A	3
B	1
W	2
C	2

- Hence, the mode is A

Handling Missing Values (Using Means and Modes)

Field1 (Numeric)	Field2 (Catrgorical)	Field3 (Numeric)	Field4 (Numeric)
21	A	300	67
17	A	250	82
17	B	280	93
24	W	334.44	76
22	C	500	85
12	A	350	66
11	A	330	82
16	A	220	84
16	C	334.44	98
17	A	420	78
18	W	360	89

Assumptions

- Assume Field 1 and Field4 don't accept decimal numbers, Hence we approximate the mean
- Field3 accepts decimal numbers, hence we don't approximate the mean value

Handling Missing Values (Using Random Values)

Field1 (Numeric)	Field2 (Catrgorical)	Field3 (Numeric)	Field4 (Numeric)
21	A	300	67
22	A	250	73
17	B	280	93
24	W	359.97	76
22	C	500	85
12	C	350	66
11	A	330	86
16	A	220	84
16	C	327.01	98
17	W	420	78
18	W	360	89

Handling Outliers

Customer ID	Zip	Gender	Income	Age	Marital Status	Transaction Amount
1001	10048	M	75000	C	M	5000
1002	J2S7K7	F	-40000	40	W	4000
1003	90210		10000000	45	S	7000
1004	6269	M	50000	0	S	1000
1005	55101	F	99999	30	D	3000

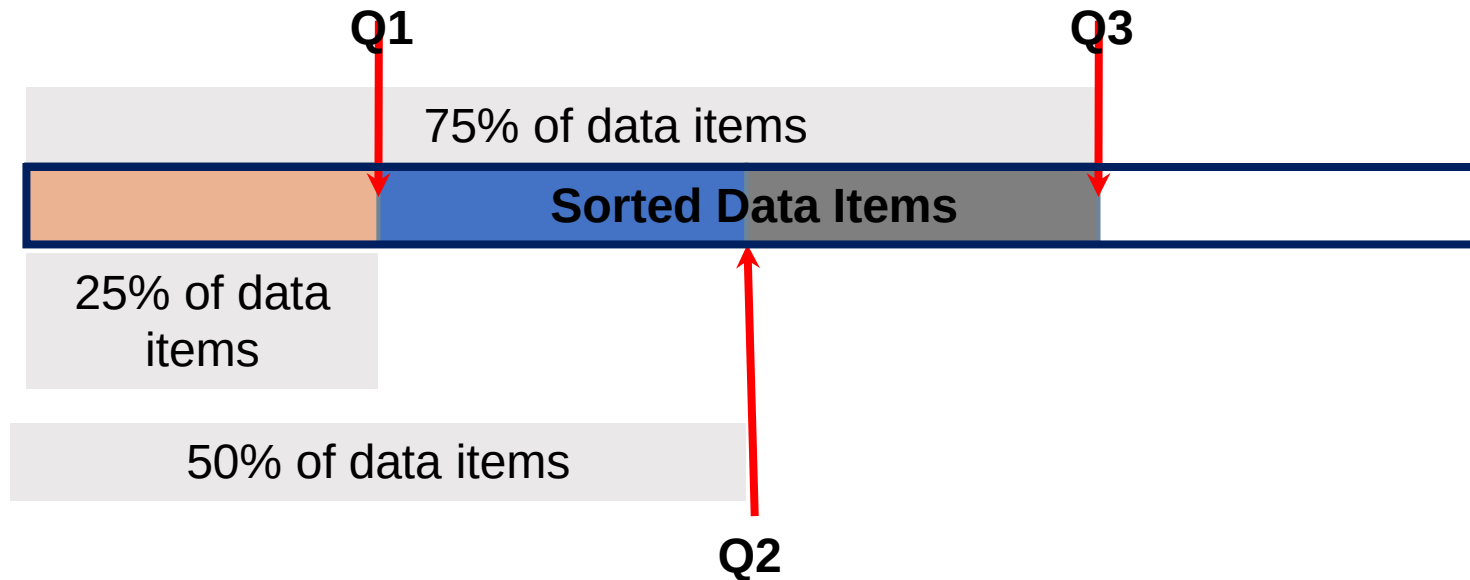
Sample Table

Data Set

Possible Outlier Values

- Outliers are data values that deviate from expected values of the rest of the data set
- Outliers are extreme values that lie near the limits of the data range or go against the trend of the remaining data.
- Normally, outliers need **more investigation** to make sure that they don't occur due to mistakes during data entry

Handling Outliers Using Inter-quartile Range



- A Quartile is any of the three values which divide the sorted data set into four equal parts
- First quartile (Q1) cuts off lowest 25% of data
- Second quartile (Q2) cuts data set in half (it is the median of the data set)
- Third quartile (Q3) cuts off highest 25% of data, or lowest 75%

Computing Q1, Q2, and Q3

- to compute Q1, Q2, and Q3, use the following method:
 - Order the given data set in ascending order.
 - Use the median to divide the ordered data set into two halves. This median is second quartile (Q2). Exclude this median (if it is one of the data items) from any further computation.
 - The first quartile (Q1) value is the median of the lower half of the data.
 - The third quartile (Q3) value is the median of the upper half of the data.

Example #1 of Computing Q1, Q2, and Q3

- compute Q1, Q2, and Q3 for the following data set:

6, 47, 49, 15, 42, 41, 7, 39, 43, 40, 36

- Order the given data set in ascending order:

6, 7, 15, 36, 39, 40, 41, 42, 43, 47, 49

- Q2 = 40 (median of the data set)
- Q1 is the median of the lower half of the data (shown in red).
- Q1 = 15
- Q3 is the median of the upper half of the data (shown in green).
- Q3 = 43

Example #2 of Computing Q1, Q2, and Q3

- compute Q1, Q2, and Q3 for the following data set:

39, 36, 7, 40, 41, 17

- Order the given data set in ascending order:

7, 17, 36, 39, 40, 41

- $Q2 = (36+39)/2 = 37.5$ (median of the data set). Note, the number of data items is even so the median is the average of the middle two data items
- The median is not a data item, hence we need to use all items in the first half of the data items to compute Q1 and the rest of the items are used to compute Q3
- $Q1 = 17$
- Q3 is the median of the upper half of the data (shown in green).
- $Q3 = 40$

- Compute the Inter-Quartile Range (**IQR**) as follows:

$$\text{IQR} = Q3 - Q1$$

- A data value is an outlier if:
 - its value is $\leq (Q1 - 1.5 \cdot \text{IQR})$, or
 - its value is $\geq (Q3 + 1.5 \cdot \text{IQR})$.

Example of Detecting Outliers using Inter-quartile Range

Customer ID	Zip	Gender	Income	Age	Marital Status	Transaction Amount
1001	10048	M	75000	C	M	5000
1002	J2S7K7	F	-40000	40	W	4000
1003	90210		10000000	45	S	7000
1004	6269	M	50000	0	S	1000
1005	55101	F	99999	30	D	3000

Sample Table

Data Set that might contains outliers

□ Data Set

75000, -40000, 10000000, 50000, 99999

Example of Detecting Outliers using Inter-quartile Range

- Data Set:

75000, -40000, 10000000, 50000, 99999

- Ordered Data Set:

-40000, 50000, 75000, 99999, 10000000

- $Q2 = 75000$
- $Q1 = (-40000 + 50000) / 2 = 5000$
- $Q3 = (99999 + 10000000) / 2 = 5049999.5$
- $IRQ = Q3 - Q1$
 $= 5049999.5 - 5000$
 $= 5044999.5$
- $Q1 - 1.5 * IRQ = 5000 - 1.5 * 5044999.5 = -7562499.5$
- $Q3 + 1.5 * IRQ = 5049999.5 + 1.5 * 5044999.5 = 12617498.75$
- All data in the data set are within range, hence there is no outliers in this example

Example of Detecting Outliers using Inter-quartile Range

Customer ID	Zip	Gender	Income	Age	Marital Status	Transaction Amount
1001	10048	M	75000	C	M	5000
1002	J2S7K7	F	40000	40	W	4000
1003	90210		10000000	45	S	7000
1004	6269	M	50000	0	S	1000
1005	55101	F	99999	30	D	3000
1006	55101	F	75000	30	M	3000

Data Set that might contains outliers

□ Data Set

75000, 40000, 10000000, 50000, 99999, 75000

Example of Detecting Outliers using Inter-quartile Range

- Data Set:

75000, 40000, 10000000, 50000, 99999, 75000

- Ordered Data Set:

40000, 50000, 75000, 75000, 99999, 10000000

- $Q2 = (75000 + 75000)/2 = 75000$
- $Q1 = 50000$
- $Q3 = 99999$
- $IRQ = Q3 - Q1$
 $= 99999 - 50000$
 $= 49999$
- $Q1 - 1.5 * IRQ = 50000 - 1.5 * 49999 = -24998.5$
- $Q3 + 1.5 * IRQ = 99999 + 1.5 * 49999 = 174997.5$
- Hence data item 10000000 is an outlier and should be re-investigated for any data-entry errors

- Noisy data are the kind of data that have incorrect values
- Some reasons for noisy data:
 - Data collection instruments may be faulty
 - Human or computer errors may occur during data entry
 - Transmission errors may occur
 - Technology limitations like buffer size, may occur during data-entry

Customer ID	Zip	Gender	Income	Age	Marital Status	Transaction Amount
1001	10048	M	75000	C	M	5000
1002	J2S7K7	F	-40000	40	W	4000
1003	90210		10000000	45	S	7000
1004	6269	M	50000	0	S	1000
1005	55101	F	99999	30	D	3000

Examples of Noisy Data

Smoothing Noisy Data

- By smoothing noisy data we can correct the errors
- Smoothing noisy data is performed by:
 - Validation and correction
 - Standardization

Validation and Correction of Noisy Data

- This step examines the data for data-entry errors and tries to correct them automatically as far as possible according to the following guidelines:
- **Spell checking** based on dictionary lookup is useful for identifying and correcting misspellings.
 - Example: **Kairo** can be spell-checked and corrected into **Cairo**
- Use **dictionaries on geographic names** and **zip codes** helps to correct address data.
 - Example: Zip code **1243456** can be detected as an error since there is no Zip code matches this value

- Check validation rules and make sure field values follow the rules; for example:
- Age is not less than certain amount and age is a positive number.
 - Example: if there is a rule governing your data says that age must be between 20 and 60, then ages of 18, 15, and 68 are detected as errors
- Each value of the categorical values belong to certain category.
 - Example: if all the categories you have are A, B, C, and D, Then if categories W or N are found they will be declared as errors

- Check the fields that have ambiguous values and check for any possible data-entry errors
 - Example: Using the same category value to refer to different meaning. “S” in “Marital Status” field could refer to “Single” or “Separated”

Standardization to Smooth Noisy Data

- Data values should be consistent and have uniform format. For example:

- Date and time entries should have a specific format

Oct. 19, 2009

10/19/2009

19/10/2009

All dates must be written with the same format that have been agreed upon (e.g.,
Day/Month/Year)

- Names and other string data should be converted to either upper or lower case.

MOHAMED AHMED

instead of

Mohamed Ahmed

- Removing prefixes and suffixes from names.

Mohamed Ahmed instead of Mr. Mohamed Ahmed

Mohamed Ahmed instead of Mohamed Ahmed, Ph.D.

- Abbreviations and encoding schemes should consistently be resolved by consulting special dictionaries or applying predefined conversion rules.
 - **US** is the standard abbreviation of **United States**

- Data inconsistency means that different data items contain discrepancies in their values
- It can occur when different data items depend on other data items and their values don't match; for example:
- Age and Birth-date; age can be computed from the birth-date, hence the value of Age must match the value computed from the birth-date
- City and Phone-area-code; each city has certain area-code
- Total-price and (unit-price and quantity); total-price can be computed from the unit-price and quantity
- These dependencies can be utilized to detect errors and substitute missing values or correct wrong values

Data Inconsistency Example

Client_Code	Place	Phone	Quantity	Unit_Price	Total_Price
101	Cairo	02-99XXXXXX	10	120	1200
102	Cairo	03-99XXXXXX	10	234	2340
102	Alexadria	03-99XXXXXX	20	400	600
104	Port-Said	03-99XXXXXX	30	100	300

Example of Inconsistent Data

Client_Code	Place	Phone	Quantity	Unit_Price	Total_Price
101	Cairo	02-99XXXXXX	10	120	1200
102	Cairo	03-99XXXXXX	10	234	2340
102	Alexadria	03-99XXXXXX	20	400	600
104	Port-Said	03-99XXXXXX	30	100	300

Data Inconsistency Marked in Red

Incorrect Area-Code

Total_Price doesn't equal (Quantity*Unit_Price)



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Thank You

