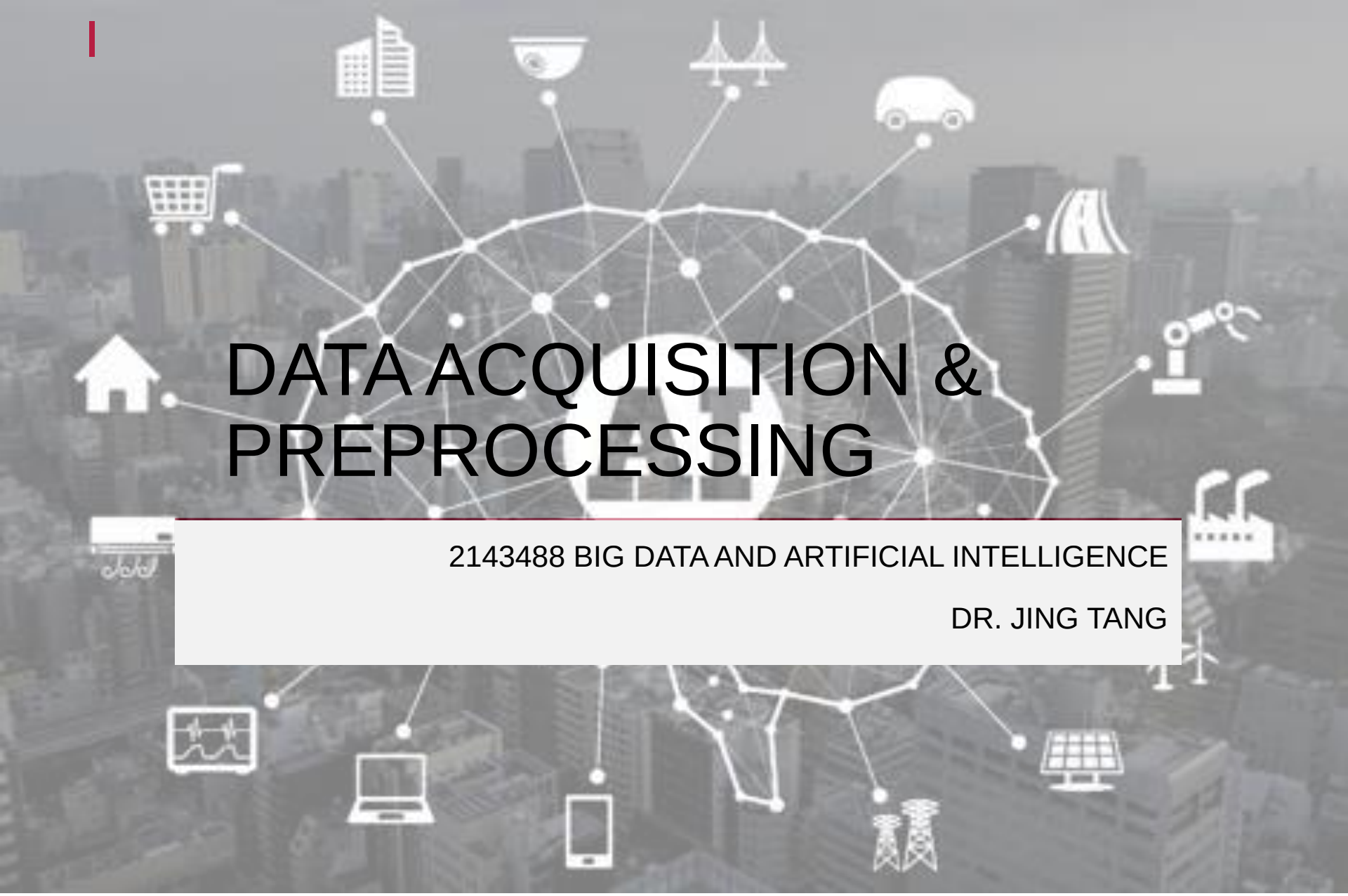


DATA ACQUISITION & PREPROCESSING

2143488 BIG DATA AND ARTIFICIAL INTELLIGENCE

DR. JING TANG

SOURCE OF DATA (1)

- **Operational Systems**: raw form of data containing errors and being scattered over several tables and files
- **Data Warehouses & Data Marts**: continuously collected, cleaned, summarized core data
- **Online Analytical Processing (OLAP)**: cleaned and organized data cubes behind BI apps, which enable to view data from multidimensions
- **Surveys**: most expensive source of data, which has limited amount, but directly address the objectives

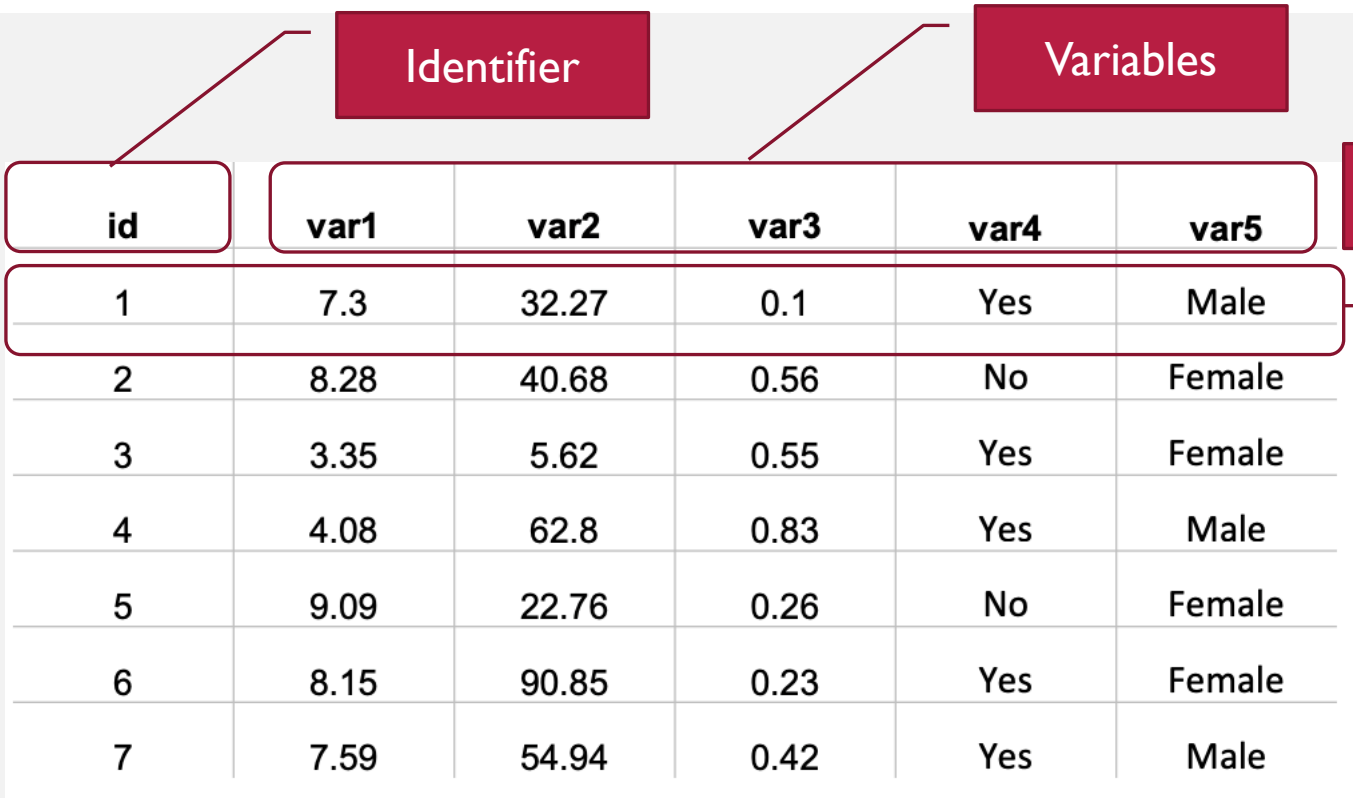
SOURCE OF DATA (2)

- **Household and Demographic Databases**: second-hand structured data from external sources
- **Other External Unstructured Databases**: social media, etc.
  - Huge amount of data are needed
  - Labelling data is tedious and error prone

VARIABLE TYPES

- **Nominal or Categorical Variables**: Lack the properties of order, scale, or distance between values. i.e., Gender, House Type, Credit Card Type
- **Ordinal or Rank or Ordered Variables**: Categorical variables with order. i.e., Income Level, Rank
- **Discrete Variables**: Countable and finite values with order, scale, and distance. i.e., Num of Products
- **Continuous Variables**: Infinite values with order, scale distance. i.e., Time, Height

CROSS-SECTIONAL DATA: IDENTIFIER, VARIABLE, RECORD



id	var1	var2	var3	var4	var5
1	7.3	32.27	0.1	Yes	Male
2	8.28	40.68	0.56	No	Female
3	3.35	5.62	0.55	Yes	Female
4	4.08	62.8	0.83	Yes	Male
5	9.09	22.76	0.26	No	Female
6	8.15	90.85	0.23	Yes	Female
7	7.59	54.94	0.42	Yes	Male

CROSS-SECTIONAL TIME SERIES DATA (PANEL DATA):

	id	year	var1	var2	var3
Group 1	1	2000	7	74.03	0.55
	1	2001	2	4.6	0.44
	1	2002	2	25.56	0.77
Group 2	2	2000	7	59.52	0.05
	2	2001	2	16.95	0.94
	2	2002	9	1.2	0.08
Group 3	3	2000	9	85.85	0.5
	3	2001	3	98.85	0.32
	3	2002	3	69.2	0.76

DATA FORMAT: ASCII (AMERICAN STANDARD CODE FOR INFORMATION INTERCHANGE)

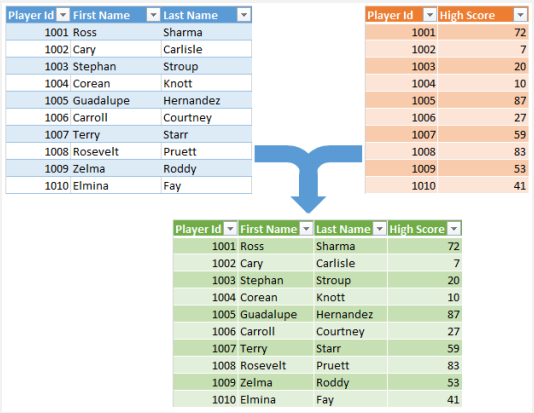
- Delimited: data is separated by comma, tab or space
  - *.csv (comma-separated value), *.txt (tab-separated), *.prn (space-separated)
  - All data package can read these formats
- Record form (or fixed): data is structured by fixed blocks. No column headings is available, so it needs a codebook to figure out the layout of the data
  - *.dat, *.txt
  - Special packages: SPSS, SAS…

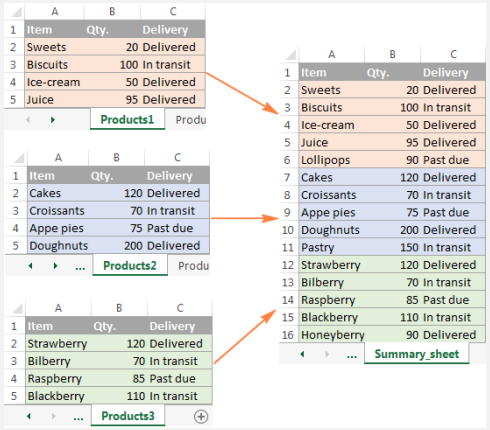
DATA ROLLUP & DATA INTEGRATION

- **Data Rollup**: Summarize data
  - Categories to Variables

id	2000_v1	2000_v2	2000_v3	2001_v1	2001_v2	2001_v3	2002_v1	2002_v2	2002_v3

  - Rollup with sums, averages, and counts
- **Data Integration**: Merge or Concatenation Multiple Tables





CHECK AFTER DATA ACQUISITION:

1) Make sure variables are in columns and observations in rows.
2) Make sure you have **all** variables you need.
3) Make sure there is **at least** one id.
4) If times series make sure you have the time (i.e., years, months) you want to include in your study.
5) Make sure to make a back-up copy of your original dataset.
6) Have the codebook handy

ADJUST DATA FORMAT

- Make sure variables are in their expected format.
  - Numeric should be numeric
  - Text should be text.

Var. 1 (Numeric)	Var. 2 (String)
1	1
2	2
2	2
4	4
3	3

Cannot do statistic with Var. 2, rather than frequencies

WHY PREPROCESS DATA?

- Data in the real world is dirty
  - **Incomplete**: lacking attribute values, lacking certain attributes of interest, or containing only aggregate data
  - **Noisy**: containing errors or outliers
  - **Inconsistent**: containing discrepancies in codes or names
- No quality data, no quality mining results!
  - **Quality decisions** must be based on **quality data**
  - Data warehouse needs **consistent integration** of quality data

EXAMPLES OF PROBLEMS FROM INACCURATE DATA

- **Marketing:** An ad campaign using low quality data and reaching out to users with irrelevant offers. This not only reduces customer satisfaction but also misses a significant sales opportunity.
- **Sales:** A sales representative failing to contact previous customers, because of not having their complete, accurate data.
- **Compliance**: Any online business receiving penalties from the government by not meeting data privacy rules for its customers. Facebook could be receiving such a penalty in the wake of Cambridge Analytica scandal.
- **Operations:** Configuring robots and other production machines based on low quality operational data, can cause causes major problems for manufacturing companies

BENEFITS OF DATA PREPROCESSING

- **Streamlined business practices**
- **Increased productivity**
- **Faster sales cycle**
- **Better decisions**

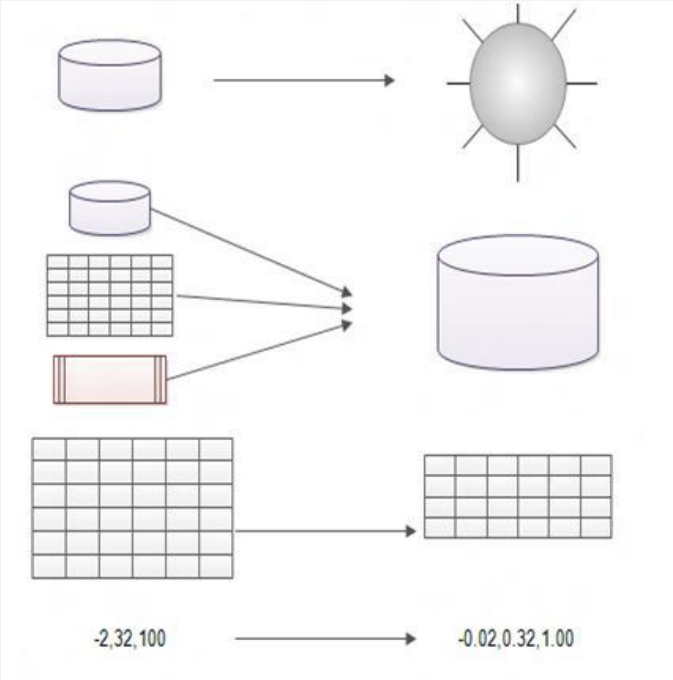
HIGH QUALITY DATA

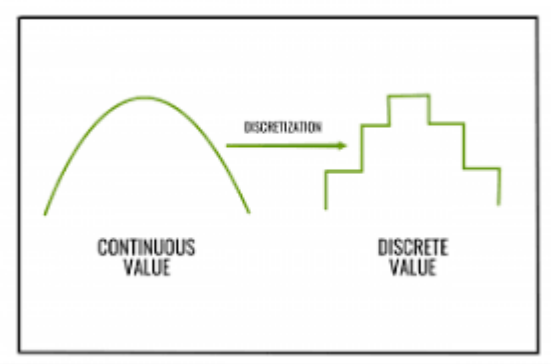
- **Validity**: meets defined business rules or constraints
- **Accuracy**: confirms to a standard or a true value
- **Completeness**
- **Consistency**: equivalency of measures across systems
- **Uniformity**: the same units of measure
- **Traceability**: being able to find the source of the data
- **Timeliness**: recent data

MAJOR TASKS IN DATA PREPROCESSING (1)

- **Data Cleaning**: Fill in missing values, smooth noisy data, identify or remove outliers, and resolve inconsistencies
- **Data Integration**: Integration of multiple databases, data cubes, or files, especially to solve inconsistency
- **Data Transformation**: Normalization and aggregation
- **Data Reduction**: Obtains reduced representation in volume but produces the same or similar analytical results
- **Data Discretization**: Part of data reduction but with particular importance, especially for numerical data

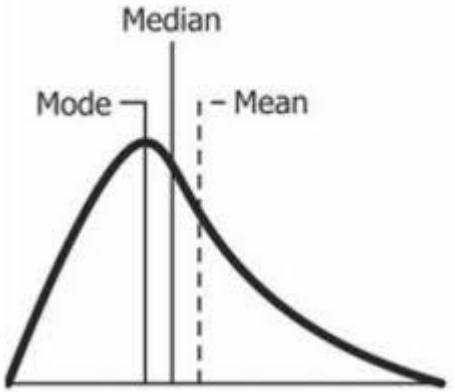
MAJOR TASKS IN DATA PREPROCESSING (2)





DESCRIPTIVE DATA SUMMARIZATION: OVERALL PICTURE OF DATA FOR SUCCESSFUL DATA PREPROCESSING

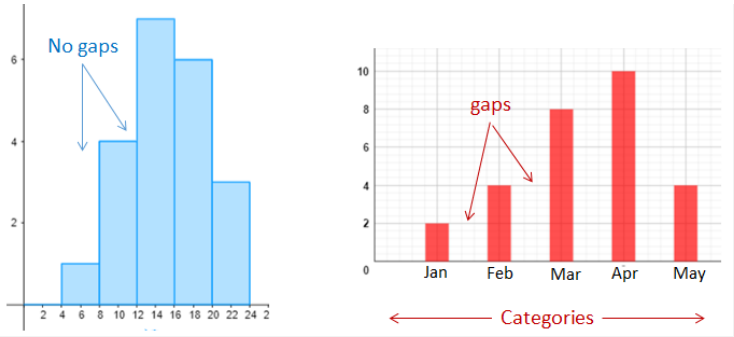
- **Location** : Central value of the variable
  - Mean
  - Median
  - Mode: unimodal, bimodal, trimodal, etc.



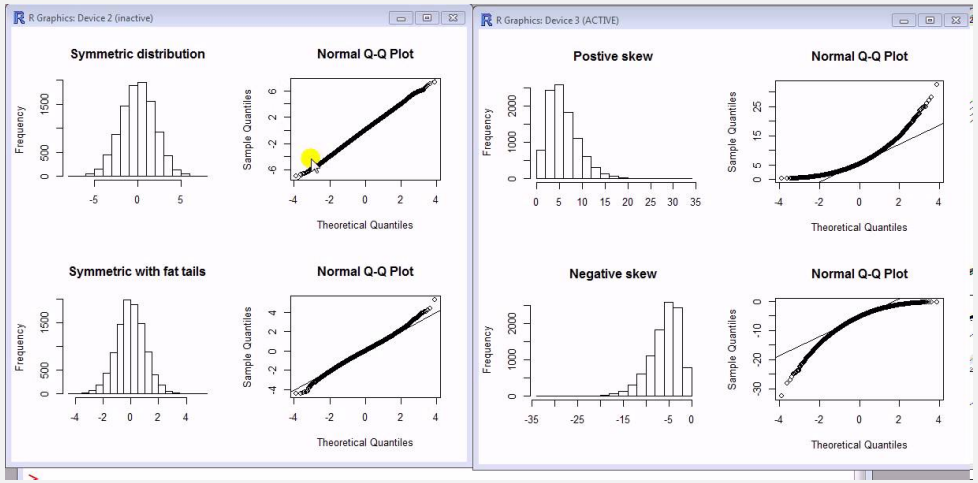
- **Variability**: the spread of the data from the center value
  - Variance
  - Standard Deviation
  - Range

GRAPHICS DISPLAYS (1)

- **Histograms vs. Bar Chart**
  - Univariable distribution

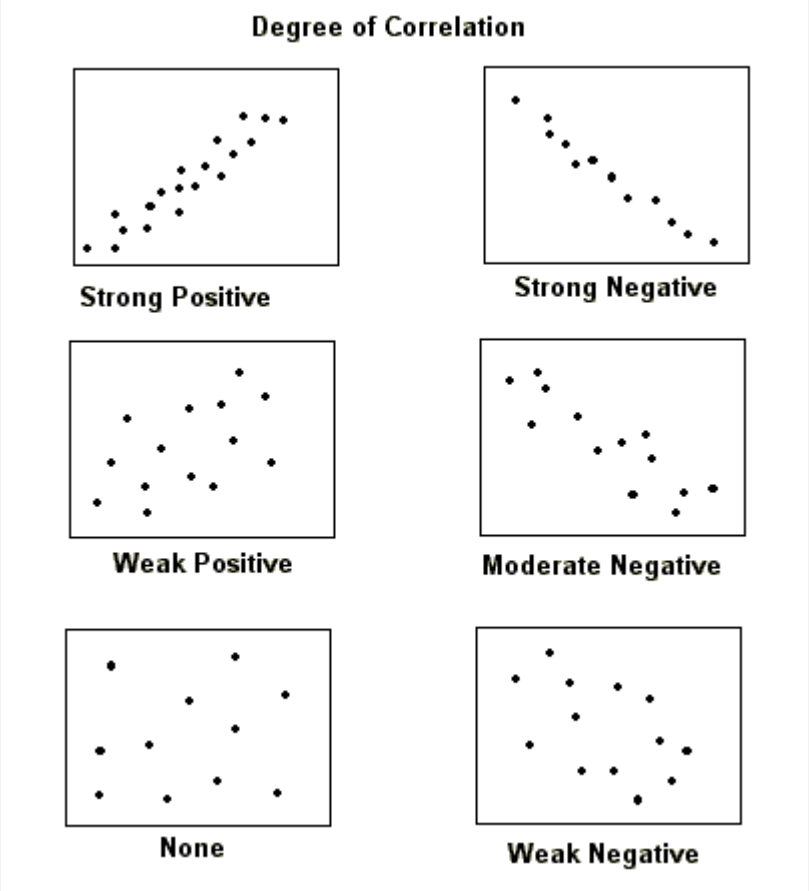


- **Quantile-Quantile (q-q) plots**
  - Compare two distributions



GRAPHICS DISPLAYS (2)

- **Scatter plots**
  - Correlation of two variables



DATA CLEANING

1) Fill in missing values
2) Identify outliers and smooth out noisy data
3) Correct inconsistent data

MISSING DATA

- Data is not always available
  - E.g., many tuples have no recorded value for several attributes, such as customer income in sales data
- Missing data may be due to
  - Equipment malfunction
  - Inconsistent with other recorded data and thus deleted
  - Data not entered due to misunderstanding
  - Certain data may not be considered important at the time of entry
  - Not register history or changes of the data
- Missing data may need to be **inferred**

HOW TO HANDLE MISSING DATA?

- **Ignore** the tuple: usually done when class label is missing (assuming the tasks in classification—not effective when the percentage of missing values per attribute varies considerably)
- **Fill in** the missing value **manually**: tedious + infeasible?
- Use a **global constant** to fill in the missing value: e.g., “unknown”, a new class?!
- Use the **attribute mean** to fill in the missing value
- Use the **most probable value** to fill in the missing value: inference- based such as Bayesian formula or decision tree

BE CAREFUL WITH NON-RESPONSE

- Getting rid of the **non-response categories**
  - ‘do not know’, ‘no answer’, ‘no applicable’, ‘not sure’, ‘refused’, etc.
  - higher values like 99, 999, 9999, etc. (or in some cases negative values)

```
. tab var1
```

Status of Nat'l Eco	Freq.	Percent	Cum.
Very well	149	10.85	10.85
Fairly well	670	48.80	59.65
Fairly badly	348	25.35	85.00
Very badly	191	13.91	98.91
Not sure	12	0.87	99.78
Refused	3	0.22	100.00
Total	1,373	100.00	

```
. tab  var1_rec
```

RECODE of var1 (Status of Nat'l Eco)	Freq.	Percent	Cum.
Very badly	191	14.06	14.06
Fairly badly	348	25.63	39.69
Fairly well	670	49.34	89.03
Very well	149	10.97	100.00
Total	1,358	100.00	

NOISY DATA

- Noise: random error or variance in a measured variable
- Incorrect attribute values may be due to
  - Faulty data collection instruments
  - Data entry problems
  - Data transmission problems
  - Technology limitation
  - Inconsistency in naming convention
- Other data problems which require data cleaning
  - Duplicate records
  - Incomplete data
  - Inconsistent data

HOW TO HANDLE NOISY DATA?

- Binning method:
  1) Sort data and partition into (equi-depth) bins
  2) Smooth by bin means, smooth by bin median, smooth by bin boundaries, etc.
- Clustering
  - Detect and remove outliers
- Combined computer and human inspection
  - detect suspicious values and check by human
- Regression
  - smooth by fitting the data into regression functions

SIMPLE DISCRETIZATION METHODS: BINNING

- **Equal-width** (distance) partitioning:
  - It divides the range into N intervals of equal size: uniform grid
  - if A and B are the lowest and highest values of the attribute, the width of intervals will be: W = (B-A)/N.
  - The most straightforward
  - But outliers may dominate presentation
  - Skewed data is not handled well.
- **Equal-depth** (frequency) partitioning:
  - It divides the range into N intervals, each containing approximately same number of samples
  - Good data scaling
  - Managing categorical attributes can be tricky.

EXAMPLE 1: BINNING METHODS FOR DATA SMOOTHING

- Sorted data for price (in dollars): 4, 8, 9, 15, 21, 21, 24, 25, 26, 28, 29, 34
- Partition into (equi-depth) bins:
  - Bin 1: 4, 8, 9, 15
  - Bin 2: 21, 21, 24, 25
  - Bin 3: 26, 28, 29, 34
- Smoothing by bin means:
  - Bin 1: 9, 9, 9, 9
  - Bin 2: 23, 23, 23, 23
  - Bin 3: 29, 29, 29, 29
- Smoothing by bin boundaries:
  - Bin 1: 4, 4, 4, 15
  - Bin 2: 21, 21, 25, 25
  - Bin 3: 26, 26, 26, 34

DATA INTEGRATION

- Data integration: combines data from multiple sources into a coherent store
- **Schema** integration
  - Integrate metadata from different sources
  - Entity identification problem: identify real world entities from multiple data sources, e.g., A.cust-id ≡ B.cust-#
- Detecting and resolving data **value** conflicts
  - For the same real-world entity, attribute values from different sources are different
  - Possible reasons: different representations, different scales, e.g., metric vs. British units

HANDLING REDUNDANT DATA

- Redundant data occur often when integration of multiple databases
  - The same attribute may have different names in different databases
  - Careful integration of the data from multiple sources may help reduce/avoid redundancies and inconsistencies and improve mining speed and quality

DATA TRANSFORMATION

- Smoothing: remove noise from data
- Aggregation: summarization, data cube construction
- Generalization: concept hierarchy climbing
- Normalization: scaled to fall within a small, specified range
  - min-max normalization
  - z-score normalization
  - normalization by decimal scaling

DATA TRANSFORMATION: NORMALIZATION

- Min-Max Normalization

$$v' = \frac{v - min_A}{max_A - min_A}(\text{newmax}_\text{A} - newmin_A) + \text{newmin}_\text{A}$$

- Z-score Normalization

$$v' = \frac{v - mean_A}{sd_A}$$

- Normalization by decimal scaling

$$v' = \frac{v}{10^j}$$

where j is the smallest integer such that $\text{Max}(|\text{v}'|) < 1$

DATA REDUCTION STRATEGIES

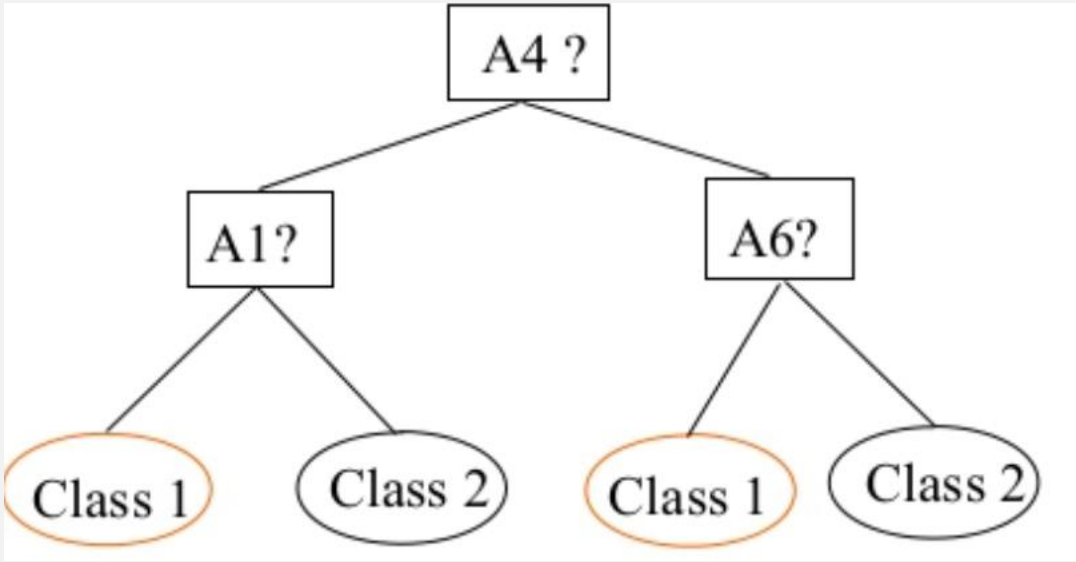
- Warehouse may store terabytes of data: Complex data analysis/mining may take a very long time to run on the complete data set
- Data reduction
  - Obtains a reduced representation of the data set that is much smaller in volume but yet produces the same (or almost the same) analytical results
- Data reduction strategies
  - Data cube aggregation
  - Dimensionality reduction
  - Numerosity reduction
  - Discretization and concept hierarchy generation

DIMENSIONALITY REDUCTION

- Feature selection (i.e., attribute subset selection):
  - Select a minimum set of features such that the probability distribution of different classes given the values for those features is as close as possible to the original distribution given the values of all features
  - Reduce # of patterns in the patterns, easier to understand

EXAMPLE 2: DECISION TREE INDUCTION

- Initial attribute set: $\{A1, A2, A3, A4, A5, A6\}$
- Reduced attribute set: $\{A1, A4, A6\}$



HISTOGRAMS

- A popular data reduction technique
- Divide data into buckets and store average (sum) for each bucket
- Can be constructed optimally in one dimension using dynamic programming
- Related to quantization problems

DISCRETIZATION

- A Three types of attributes:
  - Nominal — values from an unordered set (i.e., names, color)
  - Ordinal — values from an ordered set (i.e., ranking)
  - Continuous — real numbers (i.e., scores, times)
- Discretization:
  - Divide the range of a continuous attribute into intervals
  - Some classification algorithms only accept categorical attributes.
  - Reduce data size by discretization
  - Prepare for further analysis

DISCRETIZATION AND CONCEPT HIERARCHY

- Discretization
  - Reduce the number of values for a given **continuous attribute** by dividing the range of the attribute into **intervals.** Interval labels can then be used to replace actual data values.
- Concept hierarchies
  - Reduce the data by collecting and replacing **low level concepts** (such as numeric values for the attribute age) by **higher level concepts** (such as young, middle-aged, or senior).

DISCRETIZATION FOR NUMERIC DATA

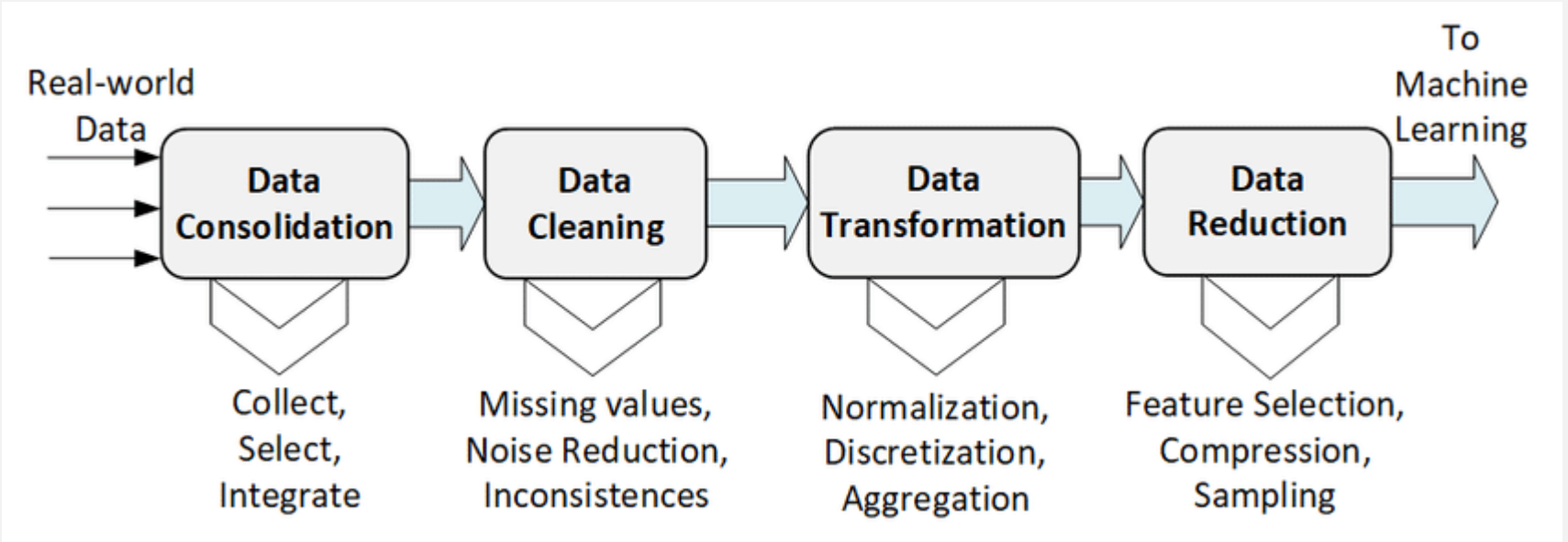
- Binning
- Histogram Analysis
- Clustering Analysis

REPLACE WIDE TO LONG

Quarter	2016	2017	2018	2019
1	2.1	2.9	3.1	3.4
2	2.2	2.9	3	3.5
3	2.4	2.8	3.3	3.6
4	2.3	2.7	3.2	3.5

Quarter	Year	value
1	2016	2.1
2	2016	2.2
3	2016	2.4
4	2016	2.3
1	2017	2.9
2	2017	2.9
3	2017	2.8
4	2017	2.7
1	2018	3.1
2	2018	3
3	2018	3.3
4	2018	3.2
1	2019	3.4
2	2019	3.5
3	2019	3.6
4	2019	3.5

SUMMARY


Real-world Data
Data Consolidation
Data Cleaning
Data Transformation
Data Reduction
To Machine Learning
Collect, Select, Integrate
Missing values, Noise Reduction, Inconsistences
Normalization, Discretization, Aggregation
Feature Selection, Compression, Sampling

HW 2: SUMMARIZE THE ANALYSIS IN A PPT WITH BRIEF EXPLANATION

- \Download 2006 microdata survey about housing for the state of Idaho using “HW2 Housing Survey.csv” and load the data into Excel\RapidMiner\Python. The code book is “HW2 Housing Survey.pdf”.
- Please answer the following question: (better in pictures)
  - How many properties are worth $1,000,000 or more?
  - How many people recorded in a house on average?
  - Draw a graph to show the relationship between the property value and the number of persons recorded?
  - Normalize family income into a range (0~1). Compare before vs after in histogram.
  - Create 5 bins for family income.