CS685: Data Mining
Data Preprocessing and Data Cleaning

Arnab Bhattacharya
arnabb@cse.iitk.ac.in

Computer Science and Engineering,
Indian Institute of Technology, Kanpur
http://web.cse.iitk.ac.in/~cs685/

1st semester, 2021-22

Mon 1030-1200 (online)

Data Quality

- Data should have the following qualities
  - Accuracy
  - Completeness
  - Consistency
  - Timeliness
  - Reliability
  - Interpretability
  - Availability

Types of Data

- Data values can be classified as discrete or continuous

Types of Data

- Data values can be classified as discrete or continuous
- *Discrete*
  - Finite or countably infinite set of values
  - Countably infinite sets have a one-to-one correspondence with the set of natural numbers

Types of Data

- Data values can be classified as discrete or continuous
- *Discrete*
  - Finite or countably infinite set of values
  - Countably infinite sets have a one-to-one correspondence with the set of natural numbers
- *Continuous*
  - Real numbers
  - Precision of measurement and machine-representation limit possibilities
  - Not continuous in the actual sense

Types of Data

- Data values can be classified as discrete or continuous
- *Discrete*
  - Finite or countably infinite set of values
  - Countably infinite sets have a one-to-one correspondence with the set of natural numbers
- *Continuous*
  - Real numbers
  - Precision of measurement and machine-representation limit possibilities
  - Not continuous in the actual sense
- Data can also be classified in other ways

Categorical Data

- Categorical data is *qualitative*

Categorical Data

- Categorical data is *qualitative*
- Nominal
  - Categories
  - Example: color
  - Operations: equal, not equal
- Binary
  - Special case of nominal
  - Example: gender, diabetic
  - Symmetric: Two cases are equally important
  - Asymmetric: One case is more important

Categorical Data

- Categorical data is *qualitative*
- Nominal
  - Categories
  - Example: color
  - Operations: equal, not equal
- Binary
  - Special case of nominal
  - Example: gender, diabetic
  - Symmetric: Two cases are equally important
  - Asymmetric: One case is more important
- Ordinal or Rank or Ordered scalar
  - Can order
  - Example: small, medium, large
  - Operations: equality, lesser, greater

Categorical Data

- Categorical data is *qualitative*
- Nominal
  - Categories
  - Example: color
  - Operations: equal, not equal
- Binary
  - Special case of nominal
  - Example: gender, diabetic
  - Symmetric: Two cases are equally important
  - Asymmetric: One case is more important
- Ordinal or Rank or Ordered scalar
  - Can order
  - Example: small, medium, large
  - Operations: equality, lesser, greater
  - Difference has no meaning

Numeric Data

- Numeric data is *quantitative*

Numeric Data

- Numeric data is *quantitative*
- Ratio-scaled
  - Has a *zero point*: absolute values are ratios of each other
  - Example: temperature in Kelvin, age, mass, length
  - Operations: difference, ratio

Numeric Data

- Numeric data is *quantitative*
- Ratio-scaled
    - Has a *zero point*: absolute values are ratios of each other
    - Example: temperature in Kelvin, age, mass, length
    - Operations: difference, ratio
- Interval-scaled
    - Measured on equal sized units
    - Example: temperature in Celsius, date
    - No zero point: absolute value has no meaning
    - Operations: difference

Data Errors and Parameters

- Errors in data due to
  - Measurement error
  - Data collection error
  - Noise: probabilistic
  - Artifact: deterministic distortions

Data Errors and Parameters

- Errors in data due to
  - Measurement error
  - Data collection error
  - Noise: probabilistic
  - Artifact: deterministic distortions
- Parameters to measure the quality of measurements
  - Precision: closeness of repeated measurements
  - Bias: systematic variation of measurements
  - Accuracy: closeness of measurements to true value

Data Errors and Parameters

- Errors in data due to
  - Measurement error
  - Data collection error
  - Noise: probabilistic
  - Artifact: deterministic distortions
- Parameters to measure the quality of measurements
  - Precision: closeness of repeated measurements
  - Bias: systematic variation of measurements
  - Accuracy: closeness of measurements to true value
- Data problems
  - Missing values
  - Noise
  - Outliers
  - Inconsistent values
  - Duplicate objects

Data Errors and Parameters

- Errors in data due to
  - Measurement error
  - Data collection error
  - Noise: probabilistic
  - Artifact: deterministic distortions
- Parameters to measure the quality of measurements
  - Precision: closeness of repeated measurements
  - Bias: systematic variation of measurements
  - Accuracy: closeness of measurements to true value
- Data problems
  - Missing values
  - Noise
  - Outliers
  - Inconsistent values
  - Duplicate objects
- *Domain knowledge* about data and attributes helps data mining

Data Preprocessing

- Data preprocessing is the process of preparing the data to be fit for data mining algorithms and methods
- Known as ETL (Extract, Transform, Load)
- It may involve one or more of the following steps
  - Data cleaning
  - Data reduction/summarization
  - Data integration
  - Data transformation

Data Cleaning

- Process of handling errors in data
- Different ways
- Filling in missing values
- Handling noise
- Removing outliers
  - One of the main methods in handling noise
- Resolving inconsistent data
  - Out of range
  - Once identified as inconsistent data, handled as missing value
- De-duplicating duplicated objects

Missing Values

- Ignore the data object

Missing Values

- Ignore the data object
- Ignore only the missing attribute during analysis

Missing Values

- Ignore the data object
- Ignore only the missing attribute during analysis
- Estimate the missing value

Missing Values

- Ignore the data object
- Ignore only the missing attribute during analysis
- Estimate the missing value
- Use a measure of overall *central tendency*
  - Mean or median
- Use a measure of central tendency from only the *neighborhood*

Missing Values

- Ignore the data object
- Ignore only the missing attribute during analysis
- Estimate the missing value
- Use a measure of overall *central tendency*
    - Mean or median
- Use a measure of central tendency from only the *neighborhood*
- Interpolation
    - Useful for temporal and spatial data

Missing Values

- Ignore the data object
- Ignore only the missing attribute during analysis
- Estimate the missing value
- Use a measure of overall *central tendency*
  - Mean or median
- Use a measure of central tendency from only the *neighborhood*
- Interpolation
  - Useful for temporal and spatial data
- Use the most probable value
  - Mode

Noise

- Noise is a *random* perturbation in the data
- It is generally assumed that magnitude of noise is smaller than magnitude of attribute of interest
  - Signal-to-noise ratio should not be too low
- White noise
  - Gaussian distribution with zero mean

Noise

- Noise is a *random* perturbation in the data
- It is generally assumed that magnitude of noise is smaller than magnitude of attribute of interest
  - Signal-to-noise ratio should not be too low
- White noise
  - Gaussian distribution with zero mean
- As opposed to noise, bias can be corrected since it is deterministic

Noise

- Noise is a *random* perturbation in the data
- It is generally assumed that magnitude of noise is smaller than magnitude of attribute of interest
  - Signal-to-noise ratio should not be too low
- White noise
  - Gaussian distribution with zero mean
- As opposed to noise, bias can be corrected since it is deterministic
- Histogram binning
  - Bin values are replaced by mean or median
  - Equi-width histograms are more common than equi-depth

Noise

- Noise is a *random* perturbation in the data
- It is generally assumed that magnitude of noise is smaller than magnitude of attribute of interest
  - Signal-to-noise ratio should not be too low
- White noise
  - Gaussian distribution with zero mean
- As opposed to noise, bias can be corrected since it is deterministic
- Histogram binning
  - Bin values are replaced by mean or median
  - Equi-width histograms are more common than equi-depth
- Regression
  - Fitting a function to describe the values
  - Small values of noise do not affect the overall fit
  - Noisy value replaced by most likely value predicted by the function

Noise

- Noise is a *random* perturbation in the data
- It is generally assumed that magnitude of noise is smaller than magnitude of attribute of interest
    - Signal-to-noise ratio should not be too low
- White noise
    - Gaussian distribution with zero mean
- As opposed to noise, bias can be corrected since it is deterministic
- Histogram binning
    - Bin values are replaced by mean or median
    - Equi-width histograms are more common than equi-depth
- Regression
    - Fitting a function to describe the values
    - Small values of noise do not affect the overall fit
    - Noisy value replaced by most likely value predicted by the function
- Outlier identification and removal

Data Duplication

- Same (or almost same) values

Data Duplication

- Same (or almost same) values
- Duplicate objects may appear during data insertion or data transfer
- Mostly due to data collection errors

Data Duplication

- Same (or almost same) values
- Duplicate objects may appear during data insertion or data transfer
- Mostly due to data collection errors
- Introduces errors in statistics about the data
- If most attributes are exact copies, then it is easy to remove
- Sometimes one or more attributes are slightly different
- *Domain knowledge* needs to be utilized to identify such cases
- Process is called de-duplication

Data Integration

- Data integration is the process of transforming multiple data sources into one single coherent source
- Useful when there are multiple databases about the same set of objects

Data Integration

- Data integration is the process of transforming multiple data sources into one single coherent source
- Useful when there are multiple databases about the same set of objects
- Schema matching and entity identification
  - Is cust_id equal to cust_number?
- Correlation analysis to reduce redundancy
- Chi-square test for categorical data
- De-duplication

Data Transformation

- Data transformation is useful when

Data Transformation

- Data transformation is useful when
  - Identifying trends
  - Normalizing to correctly get statistics
  - Applying particular data mining algorithms

Data Transformation

- Data transformation is useful when
  - Identifying trends
  - Normalizing to correctly get statistics
  - Applying particular data mining algorithms
- Smoothing of bins using histograms
- Aggregation and summarization
- Generalization
- Normalization

Normalization

- Normalization changes the range of values

Normalization

- Normalization changes the range of values
- Min-max normalization

$$x' = \frac{x - min}{max - min}$$

  - This puts range to

Normalization

- Normalization changes the range of values
- Min-max normalization

$$x' = \frac{x - min}{max - min}$$

  - This puts range to $(0, 1)$
  - If new range is (min', max')

Normalization

- Normalization changes the range of values
- Min-max normalization

$$x' = \frac{x - min}{max - min}$$

  - This puts range to $(0, 1)$
  - If new range is (min', max')

$$x' = \left(\frac{x - min}{max - min}\right)(max' - min') + min'$$

Normalization

- Normalization changes the range of values
- Min-max normalization

$$x' = \frac{x - min}{max - min}$$

  - This puts range to $(0, 1)$
  - If new range is (min', max')

$$x' = \left(\frac{x - min}{max - min}\right)(max' - min') + min'$$

- Z-score normalization

$$x' = \frac{x - \mu}{\sigma}$$

where μ is the mean and σ is the standard deviation

  - This puts range to

Normalization

- Normalization changes the range of values
- Min-max normalization

$$x' = \frac{x - min}{max - min}$$

  - This puts range to $(0, 1)$
  - If new range is (min', max')

$$x' = \left(\frac{x - min}{max - min} \right) (max' - min') + min'$$

- Z-score normalization

$$x' = \frac{x - \mu}{\sigma}$$

  where μ is the mean and σ is the standard deviation
  - This puts range to $(-\infty, +\infty)$
  - Also called standard score or z-score since it corresponds to the standard normal distribution $N(0, 1)$