Chapter 2: Getting to Know Your Data

- Data Objects and Attribute Types
- Basic Statistical Descriptions of Data
- Data Visualization
- Measuring Data Similarity and Dissimilarity
- Summary

Types of Data Sets

- Record
  - Relational records / Data matrix
    - Text documents: term-frequency vector
  - Transaction data
- Graph and network
  - Social or information networks
  - World Wide Web
  - Molecular Structures
- Ordered
  - Video data: sequence of images
  - Temporal data: time-series
  - Sequential Data: transaction sequences
  - Genetic sequence data
- Spatial, image, and multimedia:
  - Spatial data: maps
  - Image data
  - Video data

	team	coach	play	ball	score	game	win	lost	timeout	season
Document 1	3	0	5	0	2	6	0	2	0	2
Document 2	0	7	0	2	1	0	0	3	0	0
Document 3	0	1	0	0	1	2	2	0	3	0

TID	*Items*
1	**Bread, Coke, Milk**
2	**Beer, Bread**
3	**Beer, Coke, Diaper, Milk**
4	**Beer, Bread, Diaper, Milk**
5	**Coke, Diaper, Milk**

Important Characteristics of Data

- Dimensionality
  - Curse of dimensionality
- Sparsity
  - Only a small portion of presence
- Resolution
  - Patterns depend on the scale
- Distribution
  - Centrality and dispersion

	team	coach	play	ball	score	game	win	lost	timeout	season
Document 1	3	0	5	0	2	6	0	2	0	2
Document 2	0	7	0	2	1	0	0	3	0	0
Document 3	0	1	0	0	1	2	2	0	3	0

Data Objects

- Data sets are made up of data objects
- A **data object** represents a real-world entity
- Examples:
  - Sales database: customers, store items, sales
  - Medical database: patients, treatments
  - University database: students, professors, courses
- Also called *tuples, samples, examples, instances, data points, objects*
- Data objects are described by **attributes**
- Database rows -> data objects; columns ->attributes

Attributes

- **Attribute (**or **dimensions, features, variables**):
  - Data field, representing a characteristic or a feature of a data object
  - *E.g., customer _ID, name, address*
- Types:
  - Nominal
  - Binary
  - Numeric: quantitative
    - Ratio-scaled
      - Times meaningful, zero means absence (ex: weight in kg)
    - Interval-scaled:
      - Only difference meaningful (ex: temperature in celcsius)

Attribute Types

- **Nominal:** categories, states, or “names of things”
  - Has a finite number of values
  - *Hair_color = {black, blond, brown, grey, red, white}*
  - marital status, occupation, ID numbers, zip codes
- **Binary**
  - Special case of a nominal attribute with only 2 states (0 and 1)
  - *Symmetric* binary: both outcomes equally important
    - e.g., gender
  - *Asymmetric* binary: outcomes not equally important
    - e.g., medical test (positive vs. negative)
    - Convention: *assign 1 to most important outcome* (e.g., HIV positive)

Attribute Types

- **Ordinal**
  - Values have a meaningful order (ranking)
  - *Magnitude* between successive values is not known though
  - *Size* = {*small, medium, large*}, grades, army rankings

Numeric Attribute Types

- Quantity (integer or real-valued)

- **Interval-scaled**
  - Measured on a scale of **equal-sized units**
  - Values have order
    - e.g., *temperature in C˚or F˚, calendar dates*
  - No true zero-point
- **Ratio-scaled**
  - Inherent **zero-point (meaning absence)**
  - We can speak of values as being an order of magnitude larger than the unit of measurement
    - 6kg is twice as high as 3kg
    - e.g., *temperature in Kelvin, length, counts, monetary quantities*

Discrete vs. Continuous Attributes

- **Discrete Attribute**
  - Has only a *finite* or *countably infinite* set of values
    - E.g., zip codes, profession, or the set of words in a collection of documents
  - Sometimes, represented as integer variables
  - Note: Binary attributes are a special case of discrete attributes
- **Continuous Attribute**
  - Has real numbers as attribute values
    - E.g., temperature, height, or weight
  - *Practically*, real values can only be measured and represented using a finite number of digits
  - Continuous attributes are typically represented as floating-point variables

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Basic Statistical Descriptions of Data

- Motivation
  - To better understand the data: central tendency, variation and spread
- Data dispersion characteristics
  - median, max, min, quartiles, outliers, variance, etc.

Measuring the Central Tendency

- Mean (algebraic measure) (sample vs. population):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad \mu = \frac{\sum x}{N}$$

Note: *n* is sample size and *N* is population size.

- Weighted arithmetic mean:

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

- Trimmed mean:
  - taking mean after chopping extreme values

Measuring the Central Tendency

- Median:
  - Middle value if odd number of values, or average of the middle two values otherwise
  - Estimated by interpolation (for *grouped data*):

$$median = L_1 + (\frac{n/2 - (\sum freq\,l)}{freq_{median}}) * width$$

age	*frequency*
1–5	200
6–15	450
16–20	300
21–50	1500
51–80	700
81–110	44

  - Example
    - n = 3194, n/2 = 1597, L1 = 21, $\text{freq}_{\text{median}}$ = 1500
    - Numerator = 1597 – (200+450+300) = 647
    - width = (50-21) = 29
    - Median = 21+(647/1500)*(50-21)

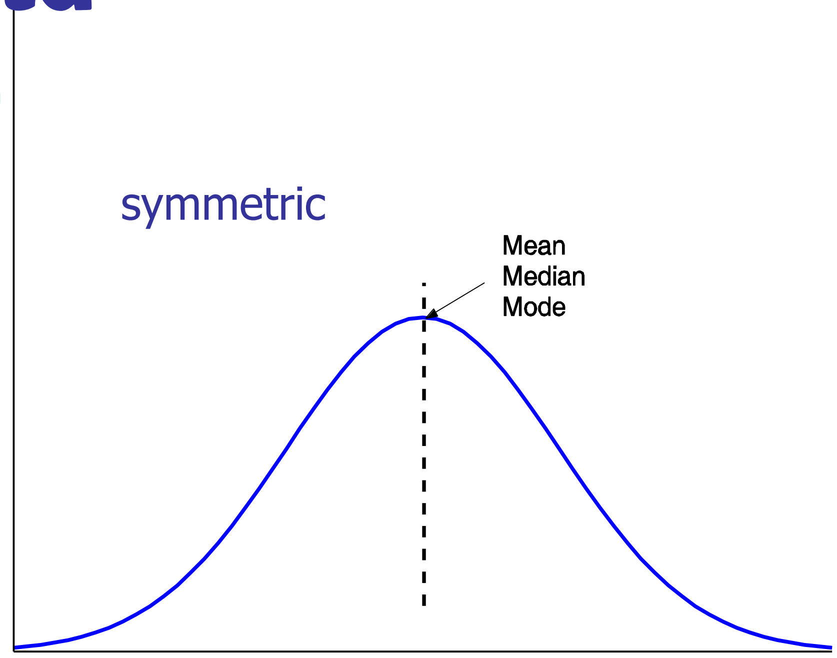
Measuring the Central Tendency

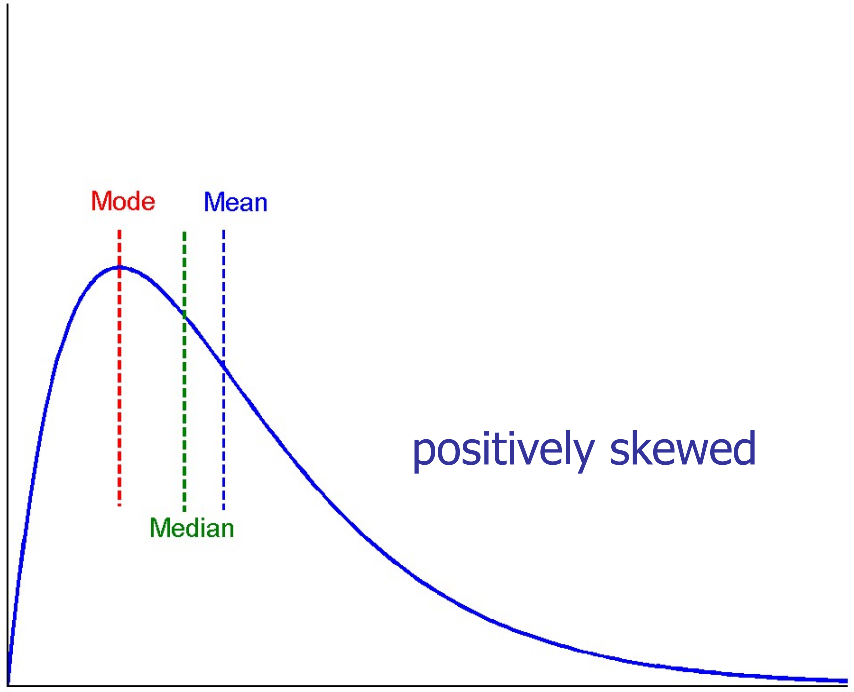
- Mode
  - Value that occurs most frequently in the data
  - Unimodal, bimodal, trimodal
  - Empirical formula:

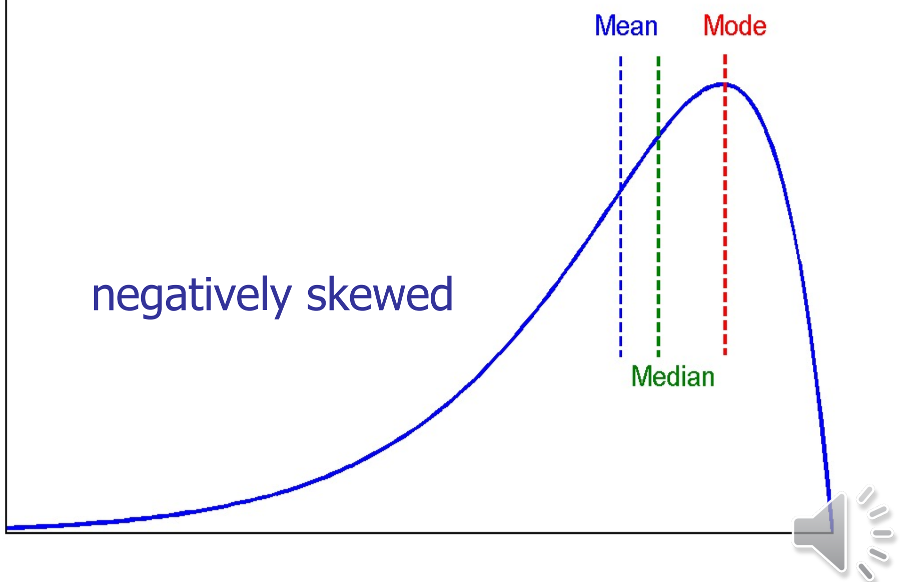
$$mean - mode = 3 \times (mean - median)$$

Symmetric vs. Skewed Data

- Median, mean, and mode of symmetric, positively and negatively skewed data







Measuring the Dispersion of Data

- Quartiles, outliers and boxplots
  - **Quartiles**: Q_1 (25th percentile), Q_3 (75th percentile)
  - **Inter-quartile range (IQR)**: IQR = $Q_3 - Q_1$
  - **Five number summary**: min, Q_1, median, Q_3, max
  - **Boxplot**: ends of the box are the quartiles; median is marked; add whiskers, and plot outliers individually
  - **Outlier**: usually, a value higher/lower than 1.5 x IQR

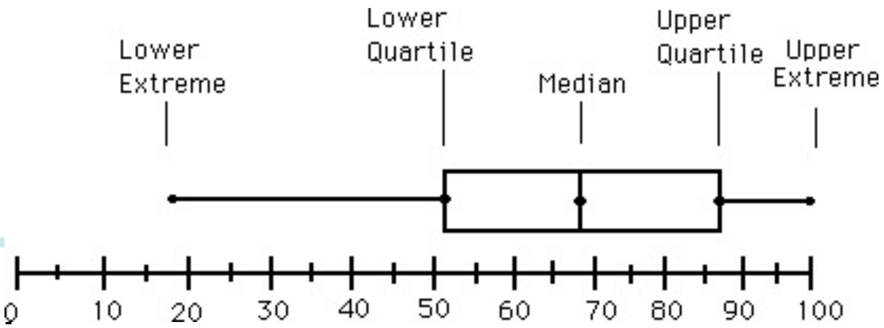
Measuring the Dispersion of Data

- Variance and standard deviation (*sample: s, population: σ)*
  - **Variance**: (algebraic, scalable computation)

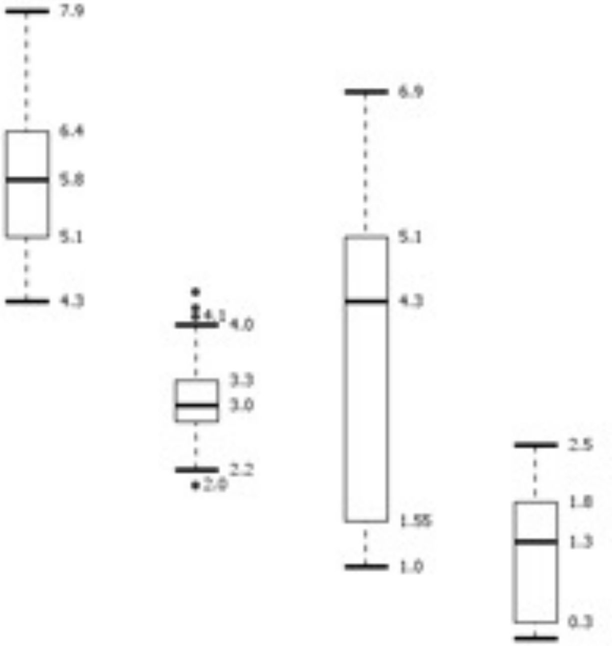
$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2 = \frac{1}{n-1}[\sum_{i=1}^{n} x_i{}^2 - \frac{1}{n}(\sum_{i=1}^{n} x_i)^2] \qquad \sigma^2 = \frac{1}{N}\sum_{i=1}^{n}(x_i - \mu)^2 = \frac{1}{N}\sum_{i=1}^{n} x_i{}^2 - \mu^2$$

  - **Standard deviation** *s (or σ)* is the square root of variance *s^2 (or σ^2)*

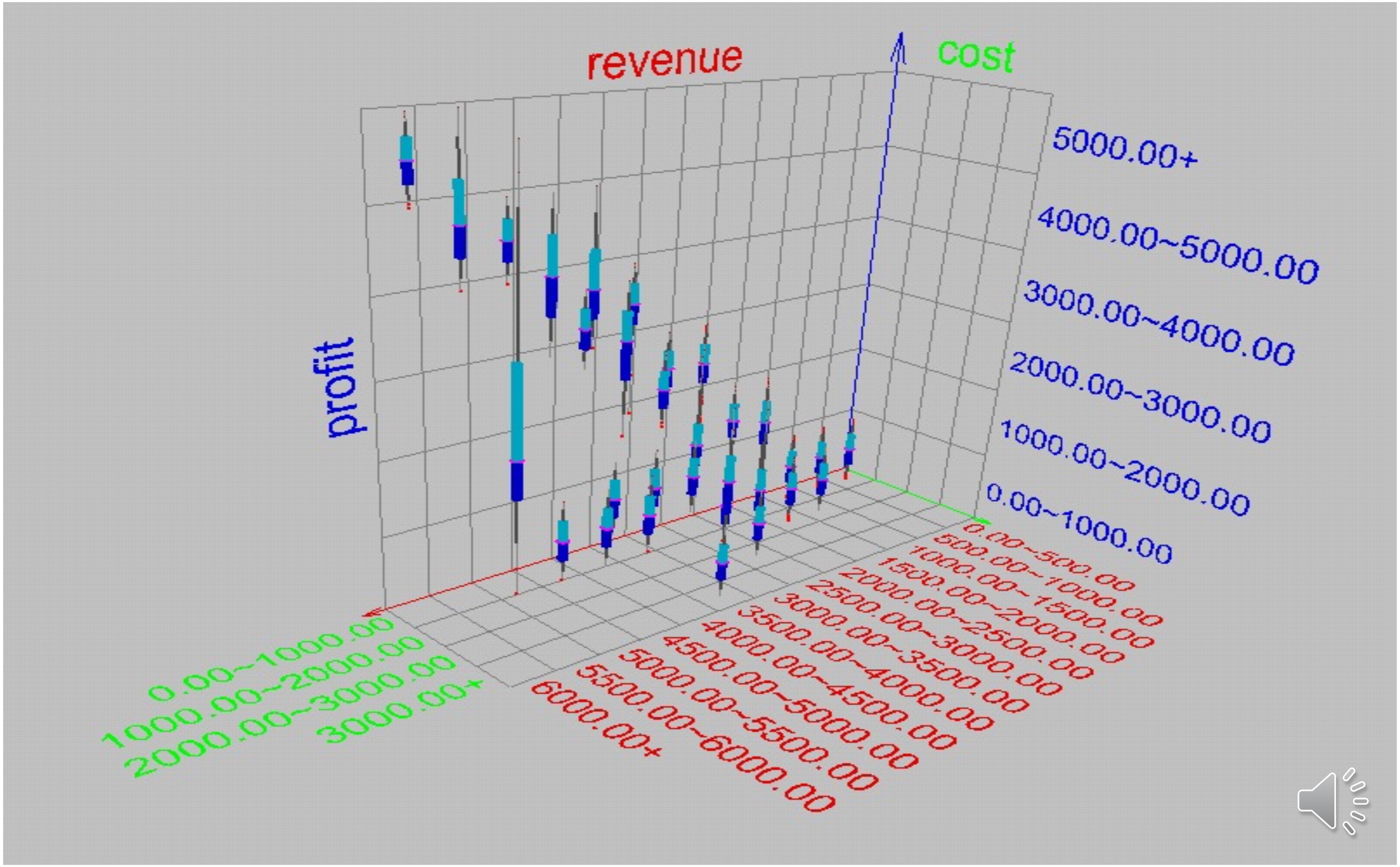
Boxplot Analysis



- **Five-number summary** of a distribution
  - Minimum, Q1, Median, Q3, Maximum
- **Boxplot**
  - Data is represented with a box
  - The ends of the box are at the first and third quartiles, i.e., the height of the box is IQR
  - The median is marked by a line within the box
  - Whiskers: two lines outside the box extended to Minimum and Maximum
  - Outliers: points beyond a specified outlier threshold, plotted individually

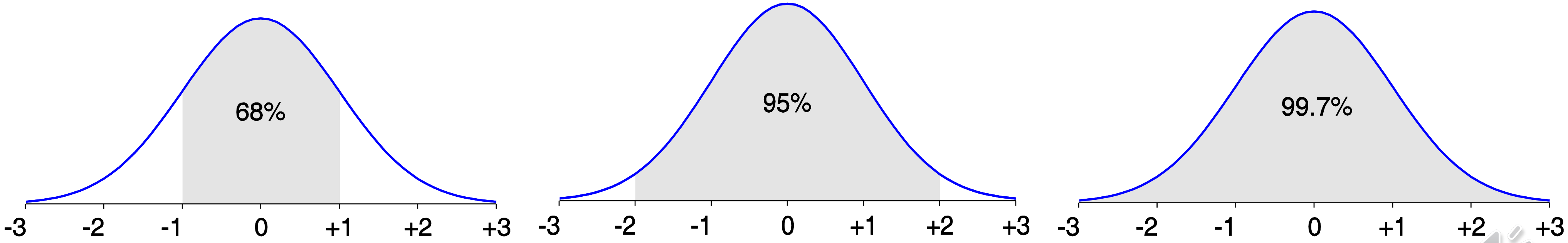


Visualization of Data Dispersion: 3-D Boxplots



Properties of Normal Distribution Curve

- The normal (distribution) curve
  - From μ–σ to μ+σ: contains about 68% of the measurements (μ: mean, σ: standard deviation)
  - From μ–2σ to μ+2σ: contains about 95% of it



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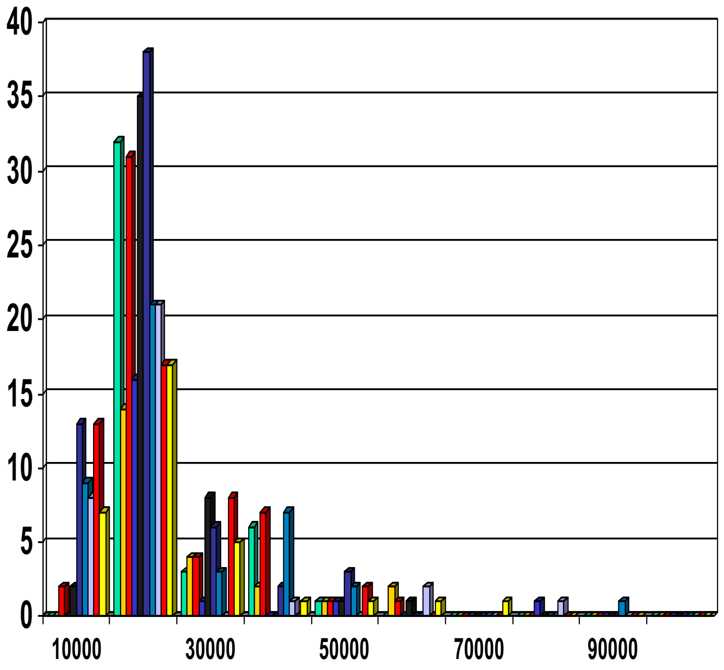
Graphic Displays of Basic Statistical Descriptions

- **Boxplot**: graphic display of five-number summary
- **Histogram**: x-axis are values, y-axis repres. frequencies
- **Quantile plot**: each value x_i is paired with f_i indicating that approximately 100 f_i% of data are $\leq x_i$
- **Quantile-quantile (q-q) plot**: graphs the quantiles of one univariant distribution against the corresponding quantiles of another
- **Scatter plot**: each pair of values is a pair of coordinates and plotted as points in the plane

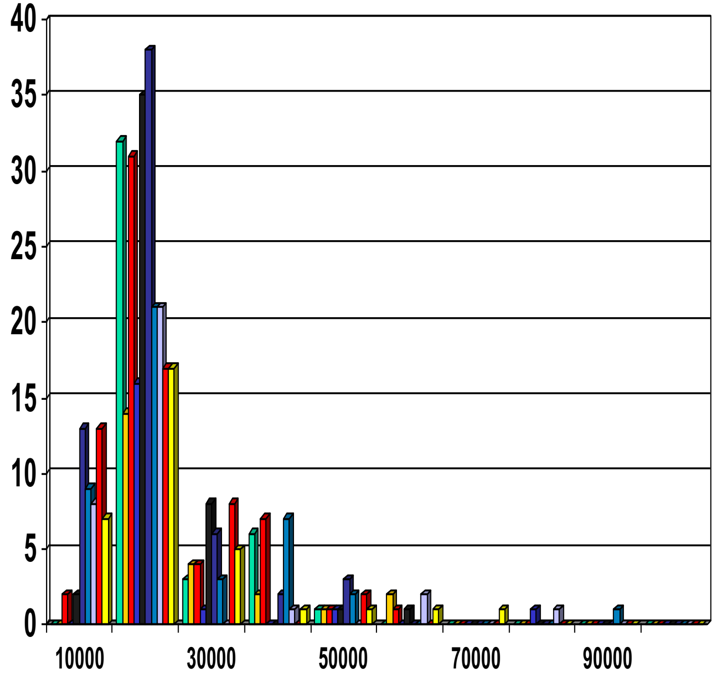
Histogram Analysis

- Histogram: Graph display of frequencies shown as bars
- It shows what proportion of cases fall into each of several categories
  - The categories are usually specified as non-overlapping intervals of some variable
  - The categories (bars) must be adjacent



Histogram Analysis

- Differs from a bar chart
  - The *area* of the bar denotes the value (histogram)
  - The *height* denotes the value (bar chart)
  - A crucial distinction when the categories are not of uniform width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