DAT630

Exploring Data

Introduction to Data Mining, Chapter 3

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Data Exploration

- Preliminary investigation of the data in order to better understand its specific characteristics
- Can aid in selecting the appropriate preprocessing and data analysis techniques
- Can even address some of the questions typically answered by data mining
  - Finding patterns by visually inspecting the data

Three major topics

- Summary statistics
- Visualization
- On-Line Analytical Processing (OLAP)

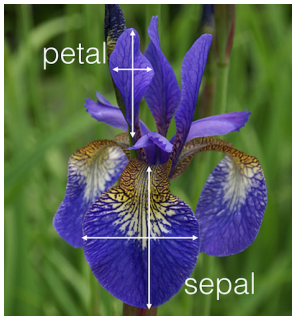
The Iris Data Set

The Iris data set

- Introduced in 1936 by Ronald Fisher
- 50 samples from each of three species of Iris
  - Iris setosa, Iris virginica, and Iris versicolor
- Four features from each sample
  - The length and the width of the sepals and petals



Four Features



Summary Statistics

Summary Statistics

- Quantities that **capture various characteristics of a** potentially **large set of values with a single number** (or a small set of numbers)
- Examples
  - Average household income
  - Fraction of students who complete a BSc in 3 years

Frequency

- The **frequency** of an attribute value is the percentage with which the value occurs in the data set
  - For example, given the attribute 'gender' and a representative population of people, the gender 'female' occurs about 50% of the time
- *x* is a categorical attribute that can take values $\{v_1,\ldots,v_k\}$ and there are *m* objects in total

$$\text{frequency}(v_i) = \frac{\text{number of objects with attribute value } v_i}{m}$$

Mode

- The **mode** of a an attribute is the most frequent attribute value
  - The notion of a mode is only interesting if attribute values have different frequencies
- The notions of frequency and mode are typically used with categorical data

Example

- What are the frequencies?
- What is the mode?

Age	Count	Frequency
0-9	3	
10-19	4	
20-29	15	
30-39	12	
40-49	8	
50-59	2	
Total	44	

Example

- What are the frequencies?
- What is the mode?

Mode →

Age	Count	Frequency
0-9	3	0,068
10-19	4	0,090
20-29	15	0,340
30-39	12	0,272
40-49	8	0,181
50-59	2	0,045
Total	44	

Percentiles

- For continuous data, the notion of a percentile is more useful
- Given an ordinal or continuous attribute *x* and a number *p* between 0 and 100, the *p*th percentile is a value x_p of *x* such that *p*% of the observed values of *x* are less than x_p
  - For instance, the *50*th percentile is the value $x_{50\%}$ such that 50% of all values of x are less than $x_{50\%}$
- min(x)= $x_{0\%}$ max(x)= $x_{100\%}$

Example

- What is the 80th percentile of this data?
- 8, 6, 3, 7, 3, 4, 1, 6, 8, 5

Example

- Sort the data
- 1, 3, 3, 4, 5, 6, 6, 7, 8, 8

80% of the values are smaller than 8

Mean and Median

- Most widely used statistics for contiuous data
- Let *x* be an attribute and $\{x_1,\ldots,x_m\}$ the values of the attribute for a set of *m* objects
- Let $\{x_{(1)},\ldots,x_{(m)}\}$ the set of values after sorting
  - I.e., $x_{(1)}=min(x)$ and $x_{(m)}=max(x)$

$$\text{mean}(x) = \bar{x} = \frac{1}{m}\sum_{i=1}^{m} x_i$$

Mean and Median (2)

- The middle value if there is an odd number of values, and the average of the two middle values if the number of values is even

$$\text{median}(x) = \begin{cases} x_{(r+1)}, & \text{if } m \text{ is odd (i.e., } m = 2r+1) \\ \frac{1}{2}(x_{(r)} + x_{(r+1)}), & \text{if } m \text{ is even (i.e., } m = 2r) \end{cases}$$

Mean vs. Median

- Both indicate the "middle" of the values
- If the distribution of values is skewed, then the median is a better indicator of the middle
- The mean is sensitive to the presence of outliers; the median provides a more robust estimate

Trimmed Mean

- To overcome problems with the traditional definition of a mean, the notion of a **trimmed mean** is sometimes used
- A percentage p between 0 and 100 is specified; the top and bottom (p/2)% of the data is thrown out; then mean is calculated the normal way
- Median is a trimmed mean with p=100%, the standard mean corresponds to p=0%

Example

- Consider the set of values {1, 2, 3, 4, 5, 90}
- What is the mean?
- What is the median?
- What is the trimmed mean with p=40%?

Example

- Consider the set of values {1, 2, 3, 4, 5, 90}
- What is the mean? **17.5**
- What is the median? (3+4)/2 = **3.5**
- What is the trimmed mean with p=40%? **3.5**
  - Trimmed values (with top-20% and bottom-20% of the values thrown out): {2,3,4,5}

Range and Variance

- To measure the dispersion/spread of a set of values (for continuous data)
- **Range**

$$\text{range}(x) = \max(x) - \min(x) = x_{(m)} - x_{(1)}$$

- **Variance***

$$\text{variance}(x) = s_x^2 = \frac{1}{m-1}\sum_{i=1}^{m}(x_i - \bar{x})^2$$

- **Standard deviation** is the square root of variance

**This variant is known as the "bias-corrected sample variance"*

Range vs. Variance

- Range can be misleading if the values are concentrated in a narrow area, but there are also a relatively small number of extreme values
- Hence, the variance is preferred as a measure of spread

Example

- What is the range and variance of the following data?
- **3 24 30 47 43 7 47 13 44 39**

Example

- What is the range and variance of the following data?
  - **3 24 30 47 43 7 47 13 44 39**
- Range: 47-3 = **44**
- Variance: **289.57**
  - mean: 29.7

More Robust Estimates of Spread

- Variance is particularly sensitive to outliers
  - The mean can be distorted by outliers; variance uses the squared difference between the mean and other values
- **Absolute Average Deviation** (AAD)

$$\mathrm{AAD}(x) = \frac{1}{m}\sum_{i=1}^{m}|x_i - \bar{x}|$$

More Robust Estimates of Spread (2)

- **Median Absolute Deviation** (MAD)

$$\mathrm{MAD}(x) = \mathrm{median}\big(|x_1 - \bar{x}|, \ldots, |x_m - \bar{x}|\big)$$

- **Interquartile Range** (IQR)

$$\mathrm{IQR}(x) = x_{75\%} - x_{25\%}$$

Exercises

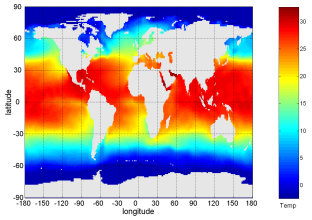
Visualization

Goals and Motivation

- **Data visualization** is the display of information in a graphic or tabular format
- The motivation for using visualization is that people can **quickly absorb** large amounts of visual information and **find patterns** in it
- Visualization is a powerful and appealing technique for data exploration
  - Humans can easily detect general patterns and trends as well as outliers and unusual patterns

Example

- Sea Surface Temperature (SST) for July 1982
  - Tens of thousands of data points are summarized in a single figure



Outline for this part

- General concepts
  - Representation
  - Arrangement
  - Selection
- Visualization techniques
  - Histograms
  - Box plots
  - Scatter plots
  - Contour plots
  - …

Representation

- Mapping of information to a visual format
- Data objects, their attributes, and the relationships among data objects are translated into graphical elements such as points, lines, shapes, and colors
  - Objects are often represented as points
  - Attribute values can be represented as the position of the points or using color, size, shape, etc.
  - Position can express the relationships among points

Arrangement

- Placement of visual elements within a display
- Can make a large difference in how easy it is to understand the data

	1	2	3	4	5	6
1	0	1	0	1	1	0
2	1	0	1	0	0	1
3	0	1	0	1	1	0
4	1	0	1	0	0	1
5	0	1	0	1	1	0
6	1	0	1	0	0	1
7	0	1	0	1	1	0
8	1	0	1	0	0	1
9	0	1	0	1	1	0

Vs.

	6	1	3	2	5	4
4	1	1	1	0	0	0
2	1	1	1	0	0	0
6	1	1	1	0	0	0
8	1	1	1	0	0	0
5	0	0	0	1	1	1
3	0	0	0	1	1	1
9	0	0	0	1	1	1
1	0	0	0	1	1	1
7	0	0	0	1	1	1

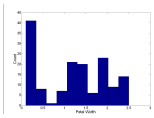
Selection

- Elimination or the de-emphasis of certain objects and attributes
- May involve the chossing a subset of attributes
  - Dimensionality reduction is often used to reduce the number of dimensions to two or three
  - Alternatively, pairs of attributes can be considered
- May also involve choosing a subset of objects
  - Visualizing all objects can result in a display that is too crowded

Outline for this part

- General concepts
- Visualization techniques
  - Histograms
  - Box plots
  - Scatter plots
  - Contour plots
  - Matrix plots
  - Parallel coordinates
  - Star plots
  - Chernoff faces

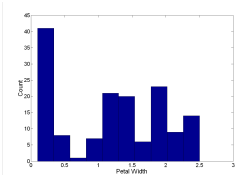
Histograms



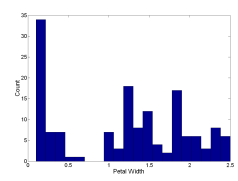
- Usually shows the distribution of values of a single variable
- Divide the values into bins and show a bar plot of the number of objects in each bin.
- The height of each bar indicates the number of objects
- Shape of histogram depends on the number of bins

Example

- Petal width

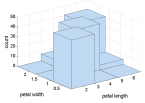


10 bins



20 bins

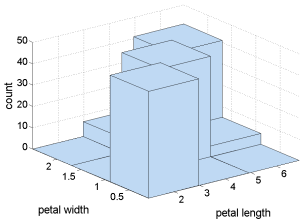
2D Histograms



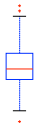
- Show the joint distribution of the values of two attributes
  - Each attribute is divided into intervals and the two sets of intervals define two-dimensional rectanges of values
- Visually more complicated, e.g., some columns may be hidden by others

Example

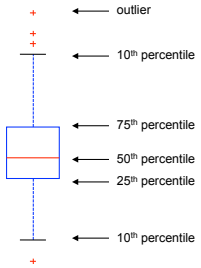
- Petal width and petal length



Box Plots

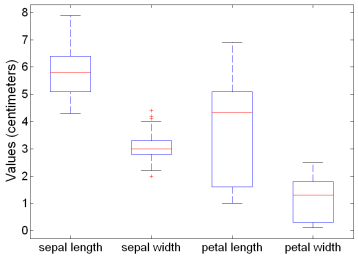


- Way of displaying the distribution of data



Example

- Comparing attributes



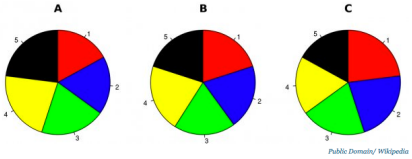
Pie Charts

- Similar to histograms, but typically used with categorical attributes that have a relatively small number of values
- Common in popular articles, but used less frequently in technical publications
  - The size of relative areas can be hard to judge
- Histograms are preferred for technical work!

The Worst Chart In The World

Walter Hickey
Jun. 17, 2013, 10:39 AM 98,768 17

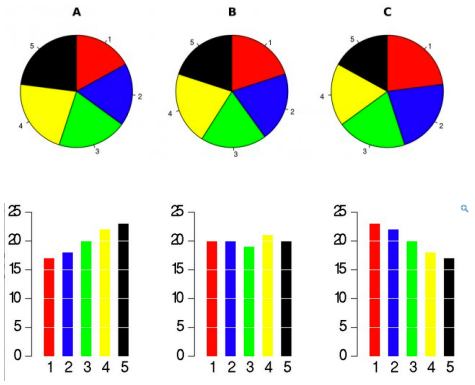
The pie chart is easily the worst way to convey information ever developed in the history of data visualization.



Public Domain/ Wikipedia

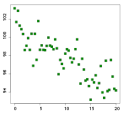
If the point of a chart is to make information more easily understandable, how is this chart working for you?

http://www.businessinsider.com/pie-charts-are-the-worst-2013-6



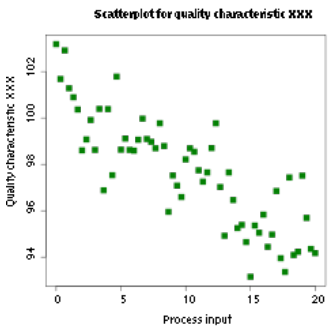
http://www.businessinsider.com/pie-charts-are-the-worst-2013-6

Scatter Plots



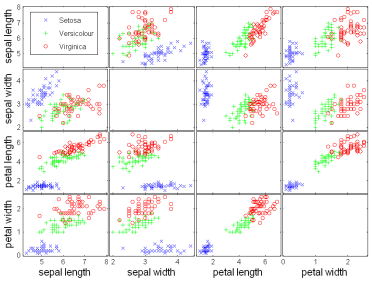
- Attributes values determine the position
- Two-dimensional scatter plots most common, but can have three-dimensional scatter plots
- Often additional attributes can be displayed by using the size, shape, and color of the markers that represent the objects

Example

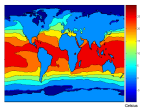


Example

- Arrays of scatter plots to summarize the relationships of several pairs of attributes

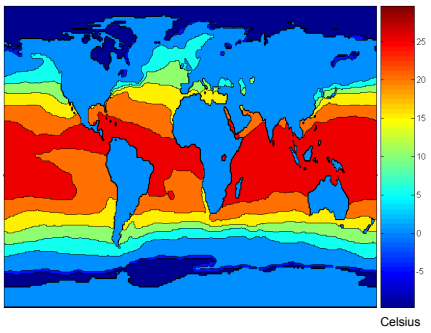


Contour Plots

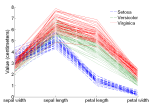


- Useful when a continuous attribute is measured on a spatial grid
- They partition the plane into regions of similar values
- The contour lines that form the boundaries of these regions connect points with equal values
- The most common example is contour maps of elevation

Example



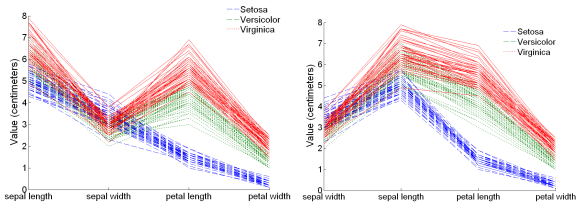
Parallel Coordinates



- Plot the attribute values of high-dimensional data
- Instead of using perpendicular axes, use a set of parallel axes
- The attribute values of each object are plotted as a point on each corresponding coordinate axis and the points are connected by a line, i.e., each object is represented as a line
- The ordering of attributes is important

Example

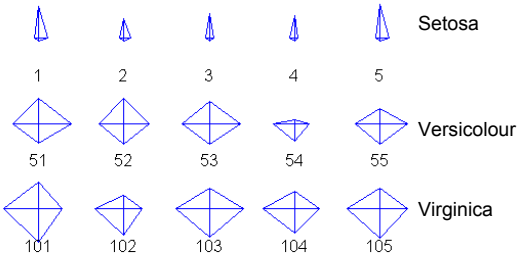
- Different ordering of attributes



Star Plots

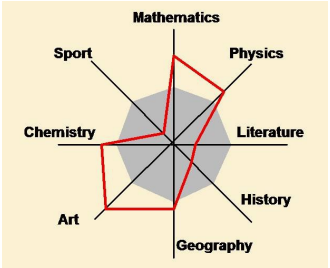
- Similar approach to parallel coordinates, but axes radiate from a central point
- The line connecting the values of an object is a polygon

Example



Example

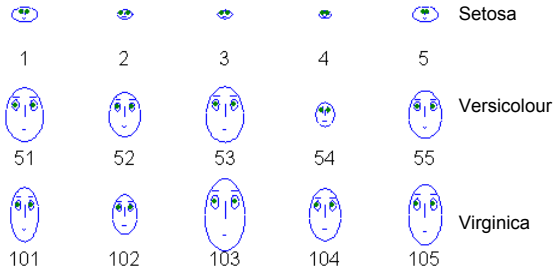
- Other useful information, such as average values or thresholds, can also be encoded



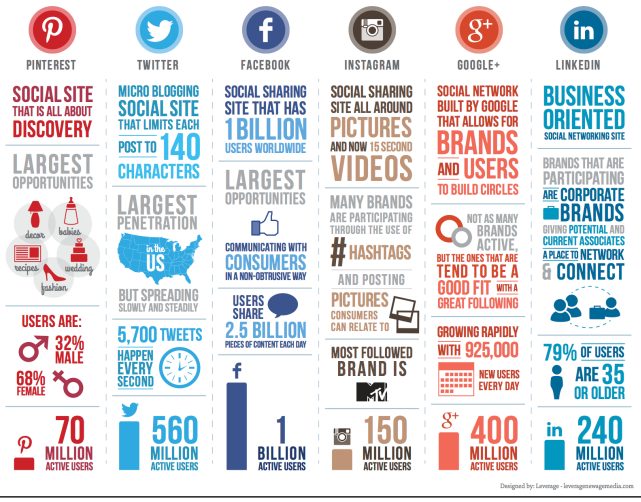
Chernoff Faces

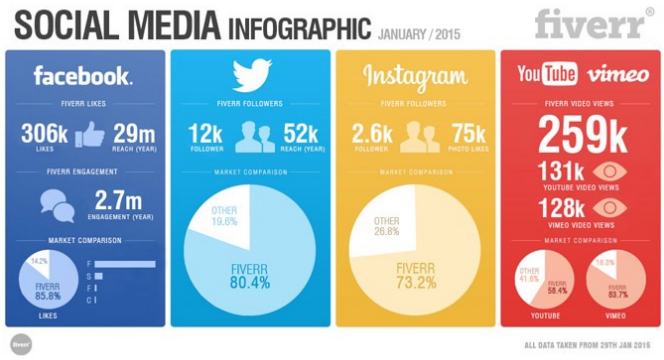
- Approach created by Herman Chernoff
- Each attribute is associated with a characteristic of a face
  - Size of the face, shape of jaw, shape of forhead, etc.
  - The value of the attribute determines the appearance of the corresponding facial characteristic
- Each object becomes a separate face
- Relies on human's ability to distinguish faces

Example



Infographics





OLAP and Multidimensional Data Analysis

OLAP

- Relational databases put data into tables, while OLAP uses a multidimensional array representation
  - Such representations of data previously existed in statistics and other fields
- There are a number of data analysis and data exploration operations that are easier with such a data representation

Converting Tabular Data

- Two key steps in converting tabular data into a multidimensional array

1. Identify which attributes are to be the dimensions and which attribute is to be the target attribute
   - The attributes used as dimensions must have discrete values
   - The target value is typically a count or continuous value, e.g., the cost of an item
   - Can have no target variable at all except the count of objects that have the same set of attribute values

Converting Tabular Data (2)

2. Find the value of each entry in the multidimensional array by summing the values (of the target attribute) or count of all objects that have the attribute values corresponding to that entry

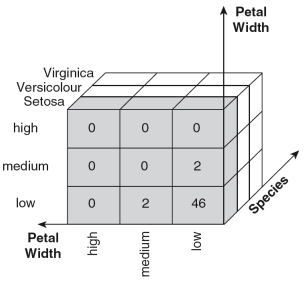
Example

- Petal width and length are discretized to have categorical values: low, medium, and high

Petal Length	Petal Width	Species Type	Count
low	low	Setosa	46
low	medium	Setosa	2
medium	low	Setosa	2
medium	medium	Versicolour	43
medium	high	Versicolour	3
medium	high	Virginica	3
high	medium	Versicolour	2
high	medium	Virginica	3
high	high	Versicolour	2
high	high	Virginica	44

Example

- Each unique tuple of petal width, petal length, and species type identifies one element of the array



Example

- Cross-tabulations can be used to show slices of the multidimensional array

Length \ Width	low	medium	high
low	46	2	0
medium	2	0	0
high	0	0	0

Length \ Width	low	medium	high
low	0	0	0
medium	0	43	3
high	0	2	2

Length \ Width	low	medium	high
low	0	0	0
medium	0	0	3
high	0	3	44

Example

- Cross-tabulations can be used to show slices of the multidimensional array

Length \ Width	low	medium	high
low	46	2	0
medium	2	0	0
high	0	0	0

Length \ Width	low	medium	high
low	0	0	0
medium	0	43	3
high	0	2	2

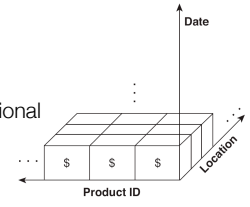
Length \ Width	low	medium	high
low	0	0	0
medium	0	0	3
high	0	3	44

Data Cube

- The key operation of a OLAP is the formation of a data cube
- A data cube is a multidimensional representation of data, together with all possible aggregates
  - Aggregates that result by selecting a proper subset of the dimensions and summing over all remaining dimensions

Example

- Consider a data set that records the sales of products at a number of company stores at various dates
  - This data can be represented as a 3 dimensional array
  - There are 3 two-dimensional aggregates, 3 one-dimensional aggregates, and 1 zero-dimensional aggregate (the overall total)



Example

- This table shows one of the two dimensional aggregates, along with two of the one-dimensional aggregates, and the overall total

product ID \ date	Jan 1, 2004	Jan 2, 2004	...	Dec 31, 2004	total
1	$1,001	$987	...	$891	$370,000
⋮	⋮			⋮	⋮
27	$10,265	$10,225	...	$9,325	$3,800,020
⋮	⋮			⋮	⋮
total	$527,362	$532,953	...	$631,221	$227,352,127

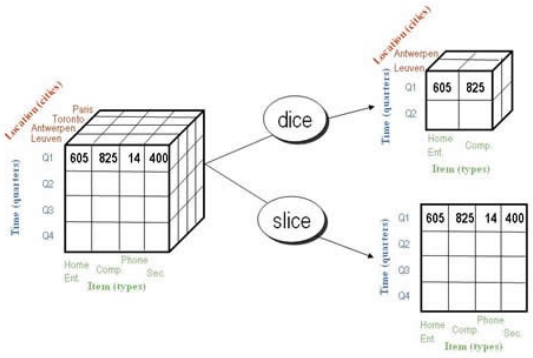
OLAP Operations

- Slicing
- Dicing
- Roll-up
- Drill-down

Slicing and Dicing

- Slicing is selecting a group of cells from the entire multidimensional array by specifying a specific value for one or more dimensions
- Dicing involves selecting a subset of cells by specifying a range of attribute values
  - This is equivalent to defining a subarray from the complete array
- In practice, both operations can also be accompanied by aggregation over some dimensions

Example



Roll-up and Drill-down

- Attribute values often have a hierarchical structure
  - Each date is associated with a year, month, and week
  - A location is associated with a continent, country, state (province, etc.), and city
  - Products can be divided into various categories, such as clothing, electronics, and furniture
- These categories often nest and form a tree
  - A year contains months which contains day
  - A country contains a state which contains a city

Example