

CPSC 340: Machine Learning and Data Mining

Data Exploration

Fall 2016

Admin

- **Assignment 1** is coming over the weekend:
 - Start soon.
- Sign up for the course page on **Piazza**.
 - www.piazza.com/ubc.ca/winterterm12016/cpsc340/home
- Sign up for a CS undergrad account:
 - <https://www.cs.ubc.ca/getacct>
- Tutorials start next week:
 - Monday 4-5 and 5-6, Tuesday 4:30-5:30, Wednesday 9-10.
 - Make sure you sign up for one.
 - No requirement to attend, but helps with assignments.
- Office hours:
 - Watch the website for details.

Outline

- 1) Typical steps in knowledge discovery from data.
- 2) Data Representations
- 3) Data Exploration

These notes roughly follow:

http://www-users.cs.umn.edu/~kumar/dmbook/dmslides/chap2_data.pdf

Data Mining: Bird's Eye View

- 1) Collect data.
- 2) Data mining!
- 3) Profit?

Unfortunately, it's often more complicated...

Data Mining: Some Typical Steps

- 1) Learn about the application.
 - 2) Identify data mining task.
 - 3) Collect data.
 - 4) Clean and preprocess the data.
 - 5) Transform data or select useful subsets.
 - 6) Choose data mining algorithm.
 - 7) Data mining!
 - 8) Evaluate, visualize, and interpret results.
 - 9) Use results for profit or other goals.
- (often, you'll go through cycles of the above)

Data Mining: Some Typical Steps

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- 2) Data Representations**
- 3) Data Exploration

What is Data?

- We'll define data as a collection of **objects**, and their **features**.

Age	Job?	City	Rating	Income
23	Yes	Van	A	22,000.00
23	Yes	Bur	BBB	21,000.00
22	No	Van	CC	0.00
25	Yes	Sur	AAA	57,000.00
19	No	Bur	BB	13,500.00
22	Yes	Van	A	20,000.00
21	Yes	Ric	A	18,000.00

- Each row is an object, each column is a feature.

Types of Data

- **Discrete features** come from an unordered set:
 - Binary: job?
 - Nominal/categorical: city.
- **Numerical features** come from ordered sets:
 - Discrete counts: age.
 - Ordinal: rating.
 - **Continuous**/real-valued: height.

Converting to Continuous Features

- Often want a real-valued object representation:

Age	City	Income
23	Van	22,000.00
23	Bur	21,000.00
22	Van	0.00
25	Sur	57,000.00
19	Bur	13,500.00
22	Van	20,000.00



Age	Van	Bur	Sur	Income
23	1	0	0	22,000.00
23	0	1	0	21,000.00
22	1	0	0	0.00
25	0	0	1	57,000.00
19	0	1	0	13,500.00
22	1	0	0	20,000.00

- We can now **interpret objects as points** in space:
 - E.g., first object is at (23,1,0,0,22000).

Bag of Words

- **Bag of words** replaces document by word counts:

The **International Conference on Machine Learning** (ICML) is the leading international [academic conference](#) in [machine learning](#)



ICML	International	Conference	Machine	Learning	Leading	Academic
1	2	2	2	2	1	1

- Ignores order, but often captures general theme.
- You can compute ‘distance’ between documents.

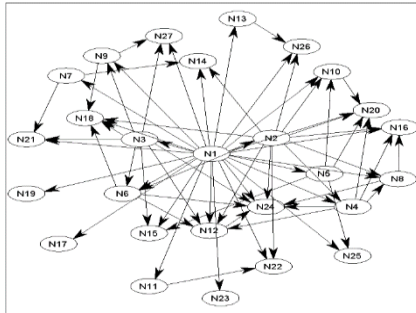
Other Data Types

- We can think of other data types in this way:
 - Images:



→
graycale
intensity

(1,1)	(2,1)	(3,1)	...	(m,1)	...	(m,n)
45	44	43	...	12	...	35



→
adjacency
matrix

N1	N2	N3	N4	N5	N6	N7
0	1	1	1	1	1	1
0	0	0	1	0	1	0
0	0	0	0	0	1	0
0	0	0	0	0	0	0

Data Cleaning

- ML+DM typically assume 'clean' data.
- Ways that data might not be 'clean':
 - Noise (e.g., distortion on phone).
 - Outliers (e.g., data entry or instrument error).
 - Missing values (no value available or not applicable)
 - Duplicated data (exact of otherwise).
- Any of these can lead to problems in analyses.
 - Want to fix these issues, if possible.
 - Some ML methods are robust to these.
 - Often, **ML is the best way to detect/fix** these.

How much data do we need?

- Assume we have a categorical variable with 50 values: {Alabama, Alaska, Arizona, Arkansas,...}.
- We can turn this into 50 binary variables.
- If each category has equal probability, **how many IID objects before we see each category once?**
- Expected value is ~ 225 .
- Coupon collector problem: $O(n \log n)$ in general.
 - [Gotta Catch'em all!](#)
- **Need more data than categories:**
 - Situation is worse if we don't have equal probabilities.
 - Typically want to see categories more than once.

Feature Aggregation

- Feature aggregation:
 - Combine features to form new features:

Van	Bur	Sur	Edm	Cal		BC	AB
1	0	0	0	0		1	0
0	1	0	0	0		1	0
1	0	0	0	0	→	1	0
0	0	0	1	0		0	1
0	0	0	0	1		0	1
0	0	1	0	0		1	0

- More province information than city information.

Feature Selection

- Feature Selection:
 - Remove features that are not relevant to the task.

SID:	Age	Job?	City	Rating	Income
3457	23	Yes	Van	A	22,000.00
1247	23	Yes	Bur	BBB	21,000.00
6421	22	No	Van	CC	0.00
1235	25	Yes	Sur	AAA	57,000.00
8976	19	No	Bur	BB	13,500.00
2345	22	Yes	Van	A	20,000.00

- Student ID is probably not relevant.

Feature Transformation

- Mathematical transformations:
 - Square, exponentiation, or take logarithm.

1,936.06
+22.21 (1.16%)
Real-time: 1:24PM EDT
INDEXSP real-time data - Disclaimer

Range 1,916.52 - 1,938.37
52 week 1,820.66 - 2,134.72
Open 1,916.52
Vol. 292.43M

G+1 {35}



1,935.74
+21.89 (1.14%)
Real-time: 1:23PM EDT
INDEXSP real-time data - Disclaimer

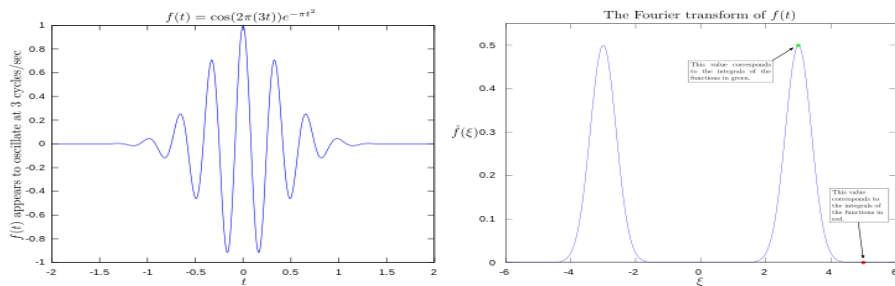
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G+1 {35}



Feature Transformation

- Mathematical transformations:
 - Square, exponentiation, or take logarithm.
 - Fourier or wavelet transform (signal data).



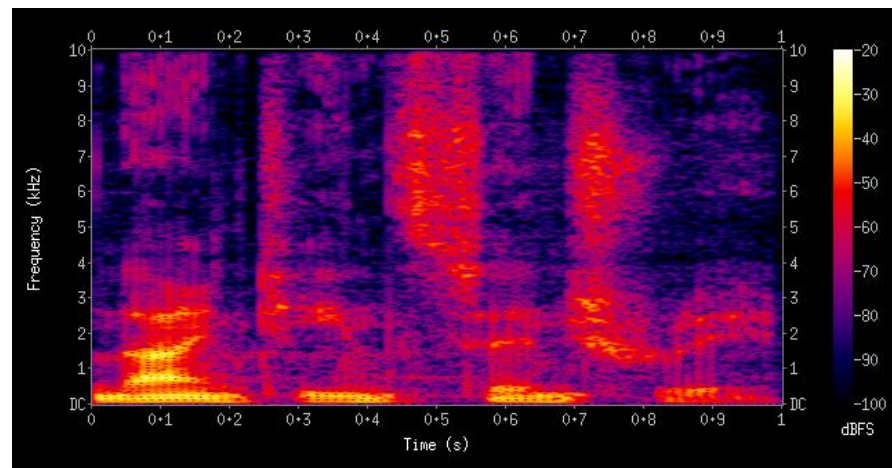
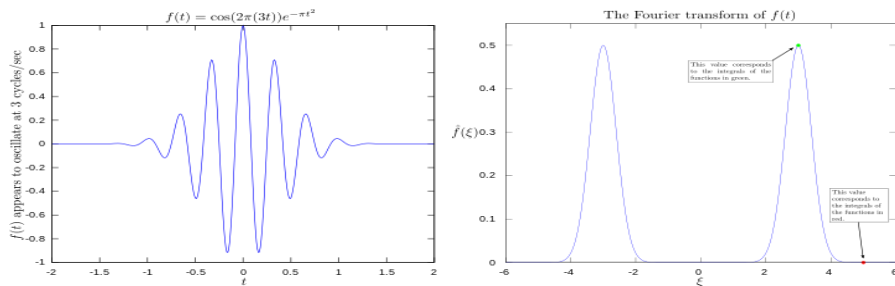
https://en.wikipedia.org/wiki/Fourier_transform

<https://en.wikipedia.org/wiki/Spectrogram>

https://en.wikipedia.org/wiki/Discrete_wavelet_transform

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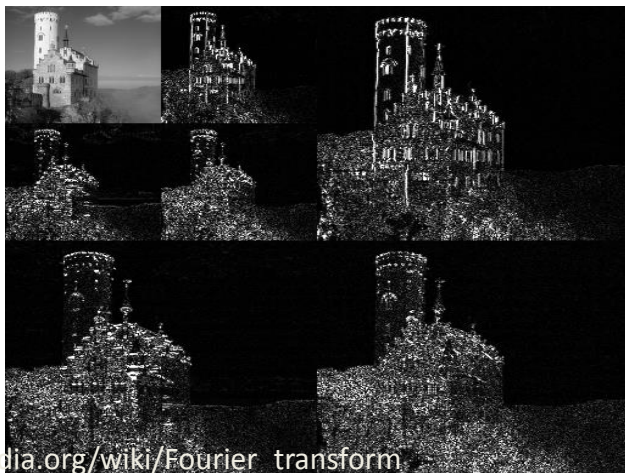


https://en.wikipedia.org/wiki/Fourier_transform
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https://en.wikipedia.org/wiki/Discrete_wavelet_transform

“Spectrogram”

Feature Transformation

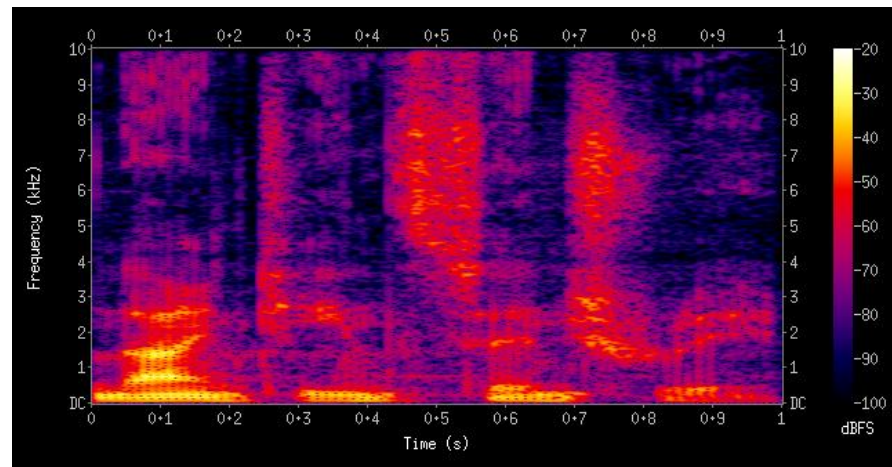
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“Spectrogram”

Feature Transformation

- Mathematical transformations:
 - Square, exponentiation, or take logarithm.
 - Fourier or wavelet transform (signal data).
 - **Discretization**: turn continuous into discrete.

Age		< 20	>= 20, < 25	>= 25
23	→	0	1	0
23		0	1	0
22		0	1	0
25		0	0	1
19		1	0	0
22		0	1	0

Feature Transformation

- Mathematical transformations:
 - Square, exponentiation, or take logarithm.
 - Fourier or wavelet transform (signal data).
 - **Discretization**: turn continuous into discrete.
 - Scaling: convert variables to comparable scales (E.g., convert kilograms to grams.)

Outline

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Data Exploration

- You should always ‘look’ at the data first.
- But how do you ‘look’ at features and high-dimensional objects?
 - Summary statistics.
 - Visualization.
 - ML + DM (later in course).

Discrete Summary Statistics

- Summary statistics for a discrete variable:
 - **Frequencies** of different classes.
 - **Mode**: category that occurs most often.
 - **Quantiles**: categories that occur more than t times:

Population by year, by province and territory
(Number)

	2014
Canada	35,540.4
Newfoundland and Labrador	527.0
Prince Edward Island	146.3
Nova Scotia	942.7
New Brunswick	753.9
Quebec	8,214.7
Ontario	13,678.7
Manitoba	1,282.0
Saskatchewan	1,125.4
Alberta	4,121.7
British Columbia	4,631.3
Yukon	36.5
Northwest Territories	43.6
Nunavut	36.6

Frequency: **13.3%** of Canadian residents live in BC.

Mode: **Ontario** has largest number of residents (38.5%)

Quantile: **6** provinces have **more than 1 million** people.

Discrete Summary Statistics

- Summary statistics **between** discrete variables:
 - **Simple matching** coefficient:
 - How many times two variables are the same.
 - $SMC = (C_{11} + C_{00}) / (C_{00} + C_{01} + C_{10} + C_{11})$.
 - **Jaccard** coefficient for binary variables:
 - Intersection divided by union of '1' values.
 - $C_{11} / (C_{01} + C_{10} + C_{11})$.

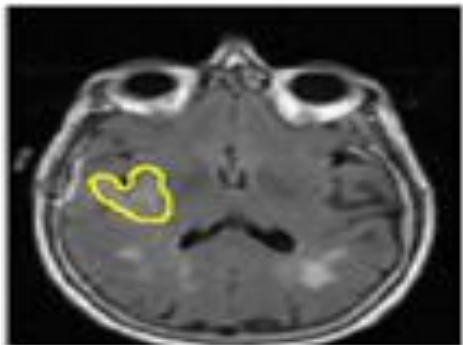
Simple Matching vs. Jaccard

A	B
1	0
1	0
1	0
0	1
0	1
1	0
0	0
0	0
0	1

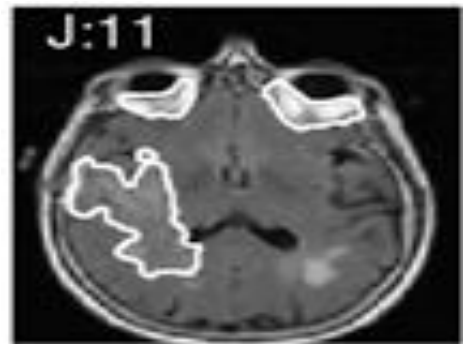
$$\begin{aligned}\text{Sim}(A,B) &= (C_{11} + C_{00}) / (C_{00} + C_{01} + C_{10} + C_{11}) \\ &= (0 + 2) / (2 + 3 + 3 + 0) \\ &= 2/7.\end{aligned}$$

$$\begin{aligned}\text{Jac}(A,B) &= C_{11} / (C_{01} + C_{10} + C_{11}) \\ &= 0 / (3 + 3 + 0) \\ &= 0.\end{aligned}$$

Simple Matching vs. Jaccard



$$\text{Sim}(A,B) = 0.91$$



$$\text{Jac}(A,B) = 0.11$$

Continuous Summary Statistics

- Measures of location:
 - **Mean**: average value (sensitive to outliers).
 - **Median**: value such that half points are larger/smaller.
 - **Quantiles**: value such that 't' points are larger.
- Measures of spread:
 - **Range**: minimum and maximum values.
 - **Variance**: measures how far values are from mean.
 - **Intequantile ranges**: difference between quantiles.

Continuous Summary Statistics

- Data: [0 1 2 3 3 5 7 8 9 10 14 15 17 200]
- Measures of location:
 - $\text{Mean}(\text{Data}) = 21$
 - $\text{Mode}(\text{Data}) = 3$
 - $\text{Median}(\text{Data}) = 7.5$
 - $\text{Quantile}(\text{Data}, 0.5) = 7.5$
 - $\text{Quantile}(\text{Data}, 0.25) = 3$
 - $\text{Quantile}(\text{Data}, 0.75) = 14$
- Measures of spread:
 - $\text{Range}(\text{Data}) = [0 \ 200]$.
 - $\text{Std}(\text{Data}) = 51.79$
 - $\text{IQR}(\text{Data}, .25, .75) = 11$
- Notice that **mean and std are more sensitive to extreme values.**

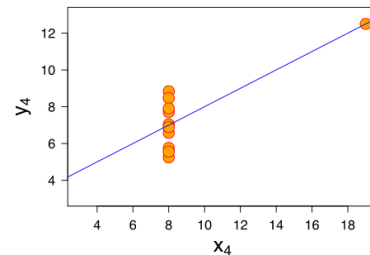
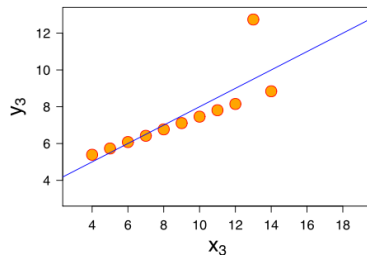
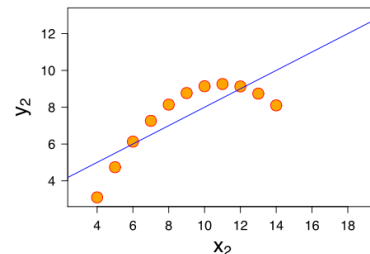
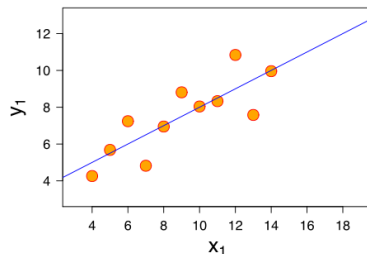
Continuous Summary Statistics

- Measures **between** continuous variables:
 - **Correlation:**
 - Does one increase/decrease proportionally as the other increases?
 - **Rank correlation:**
 - Does one increase/decrease as the other increases?
 - **Euclidean distance:**
 - How far apart are the values?
 - **Cosine similarity:**
 - What is the angle between them?

Limitations of Summary Statistics

- On their own **summary statistic can be misleading.**
- [Why not to trust statistics](#)

- Amcomb's quartet:
 - Almost same means.
 - Almost same variances.
 - Alsmot same correlations.
 - Look completely different.

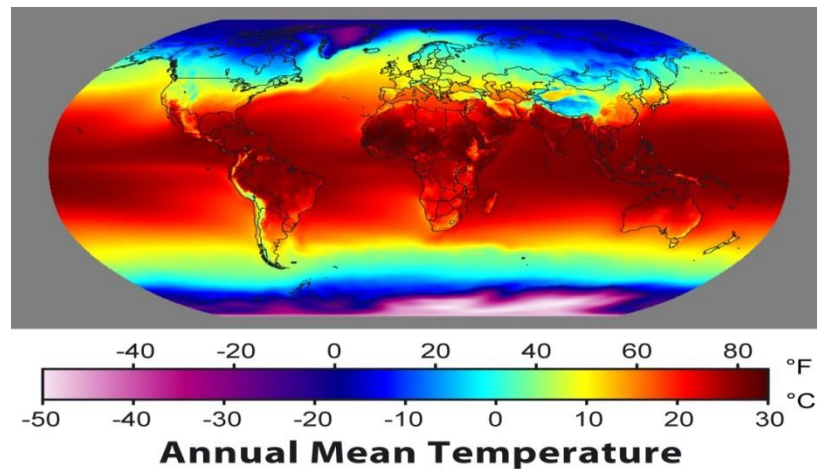


Visualization

- You can learn a lot from **2D plots** of the data:
 - Patterns, trends, outliers, unusual patterns.

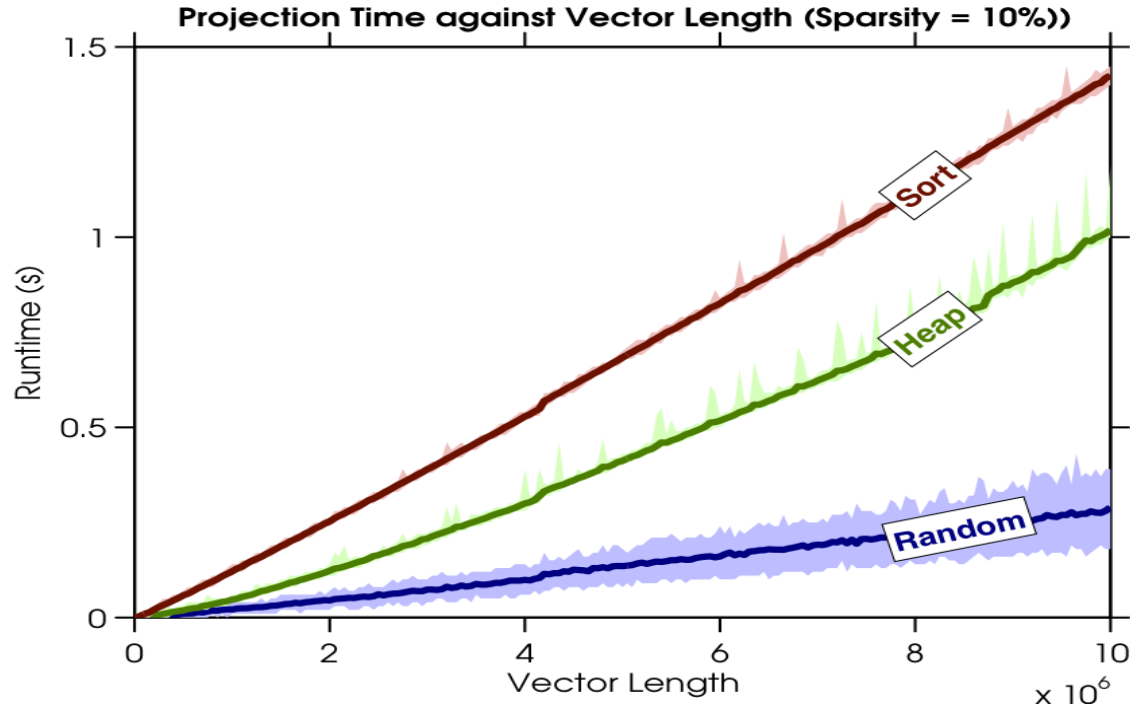
Lat	Long	Temp
0	0	30.1
0	1	29.8
0	2	29.9
0	3	30.1
0	4	29.9
...

vs.



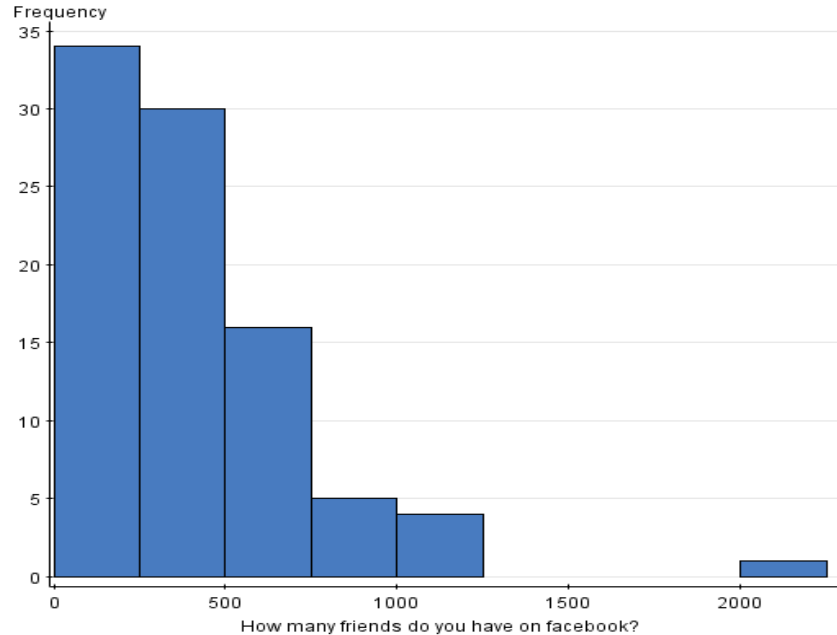
Basic Plot

- Visualize one variable as a function of another.



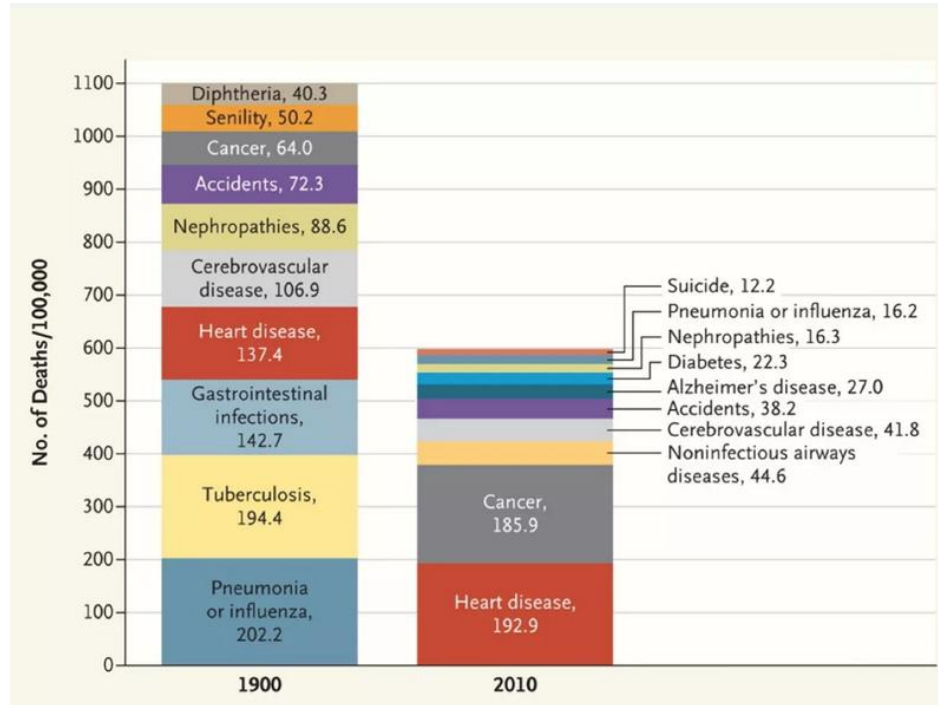
Histogram

- Histograms display distribution of a variable.

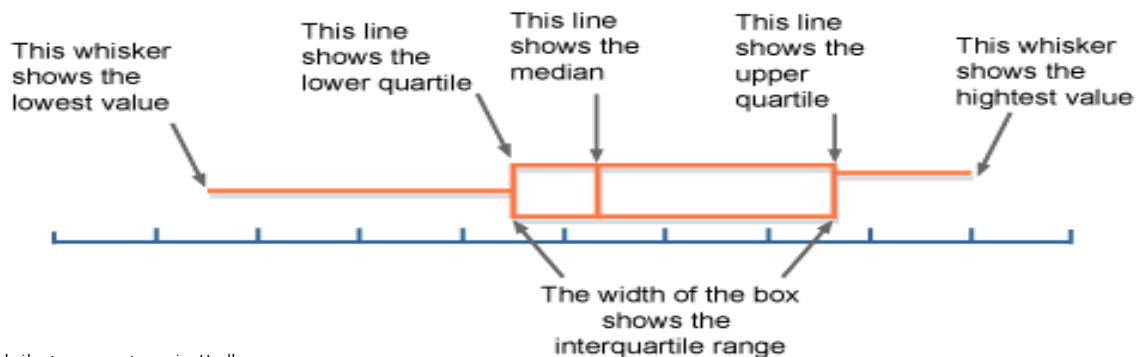


Histogram

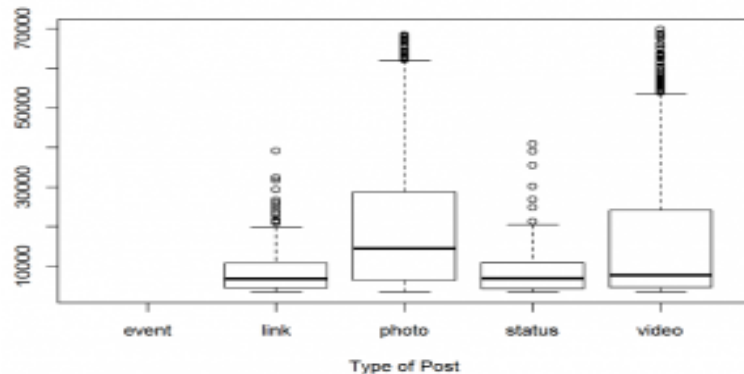
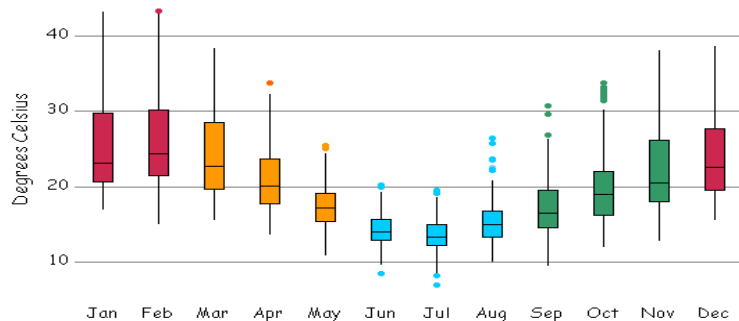
- Histogram with grouping:



Box Plot



Maximum daily temperature in Melbourne



<http://www.bbc.co.uk/schools/gcsebitesize/maths/statistics/representingdata3hirev6.shtml>

<http://www.scc.ms.unimelb.edu.au/whatisstatistics/weather.html>

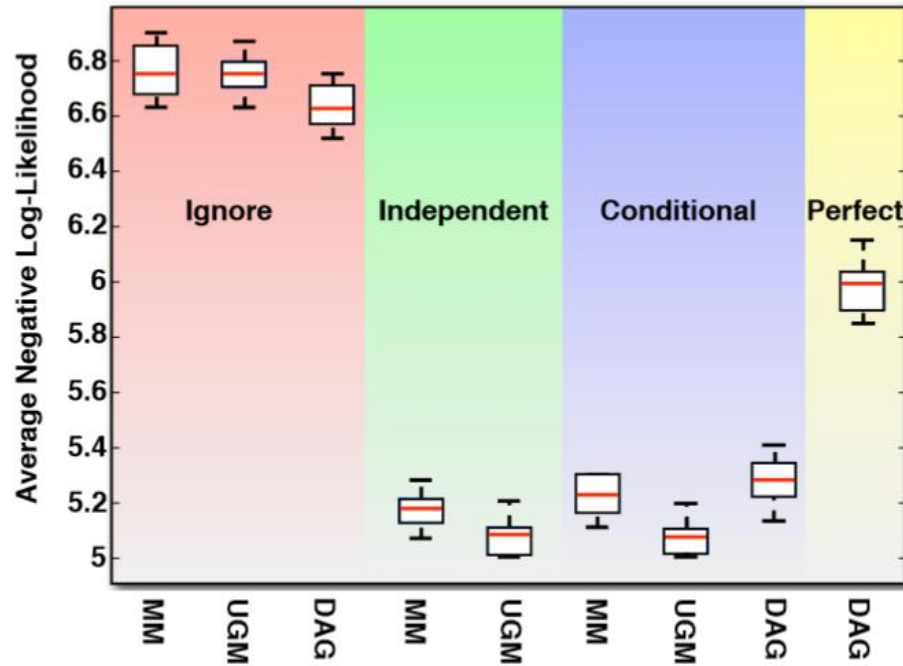
Box Plot

- Photo from CTV Olympic coverage in 2010:



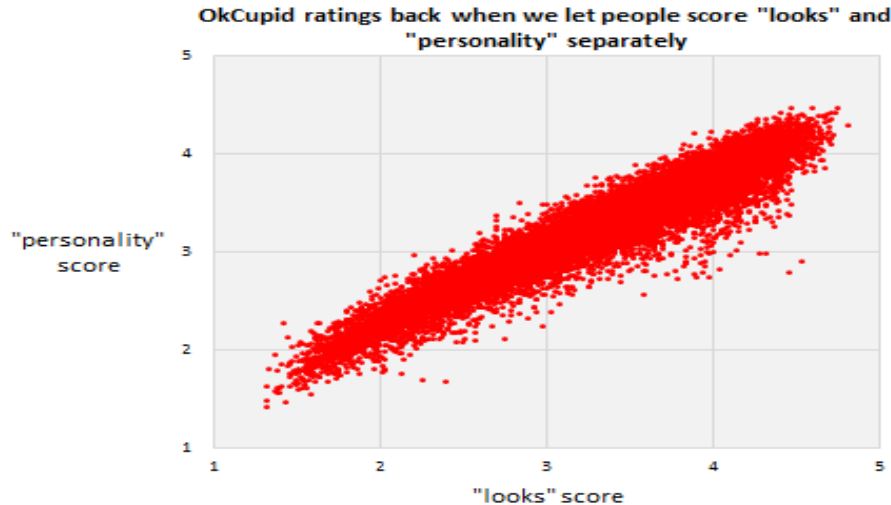
Box Plots

- Box plot with grouping:



Scatterplot

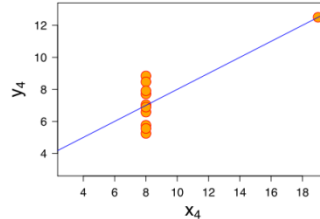
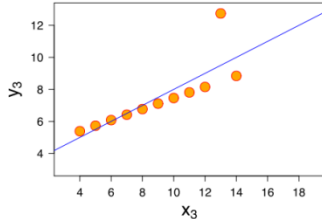
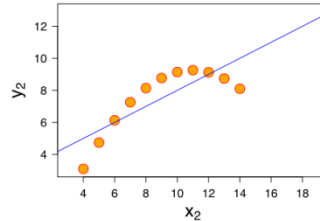
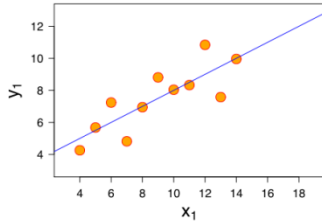
- Look at distribution of two features:
 - Feature 1 on x-axis.
 - Feature 2 on y-axis.



- Shows correlation between "personality" score and "looks" score.

Scatterplot

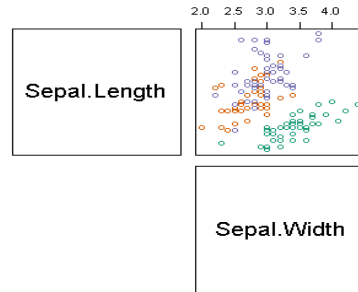
- Look at distribution of two features:
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- Shows correlation between “personality” score and “looks” score.
- But scatterplots let you see more complicated patterns.

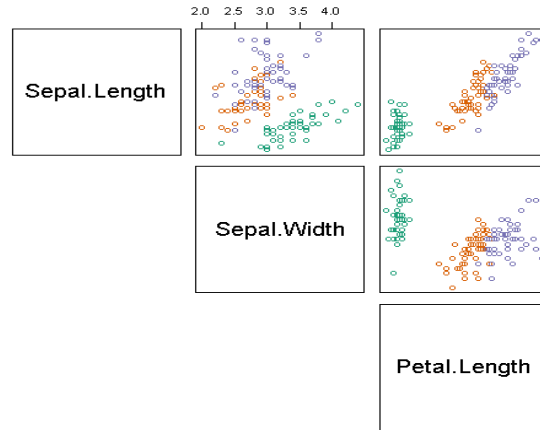
Scatterplot Arrays

- For multiple variables, can use **scatterplot array**.



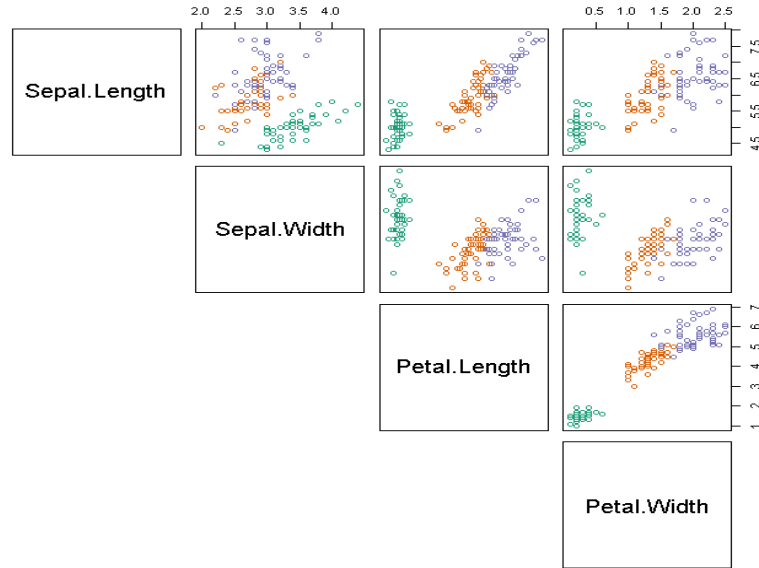
Scatterplot Arrays

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Scatterplot Arrays

- For multiple variables, can use **scatterplot array**.



- Colors can indicate a third categorical variable.

Map Coloring

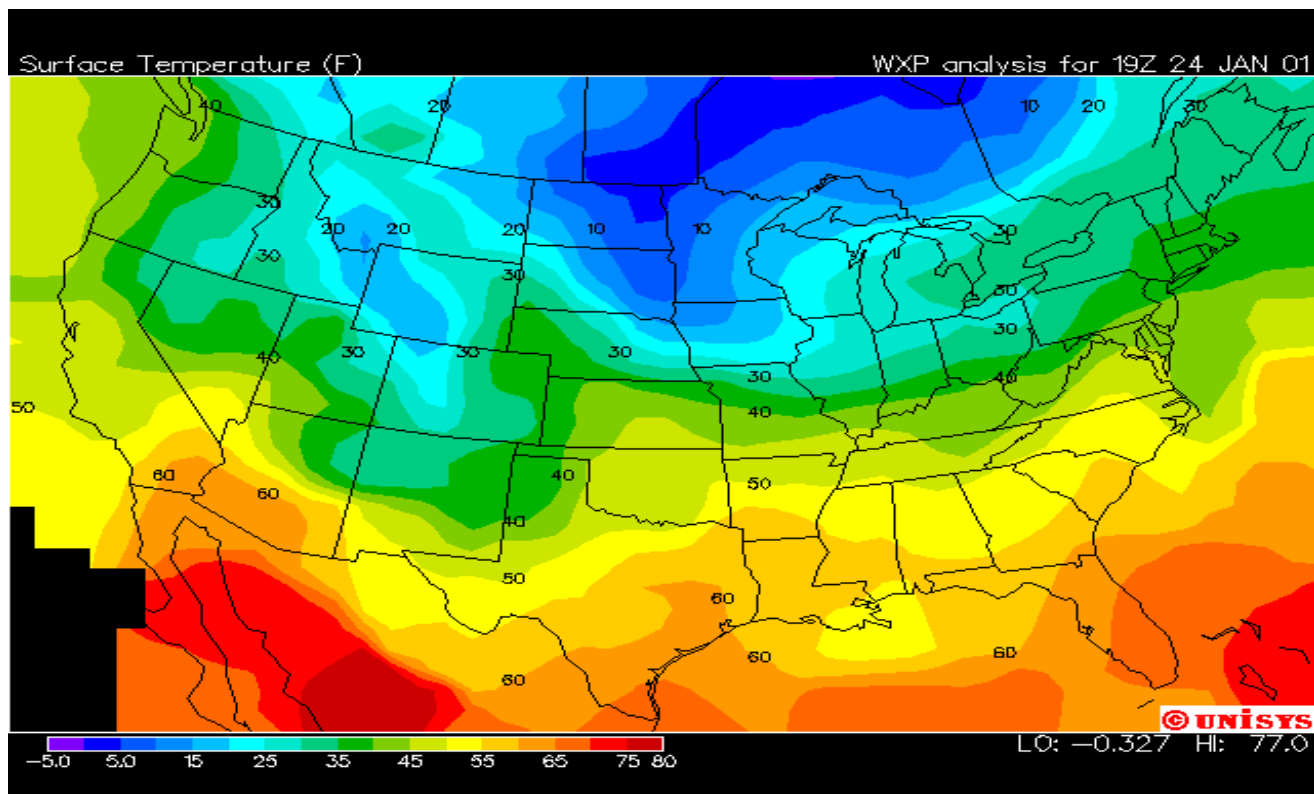
- Color/intensity can represent feature of region.

Evelyn's popularity over time:



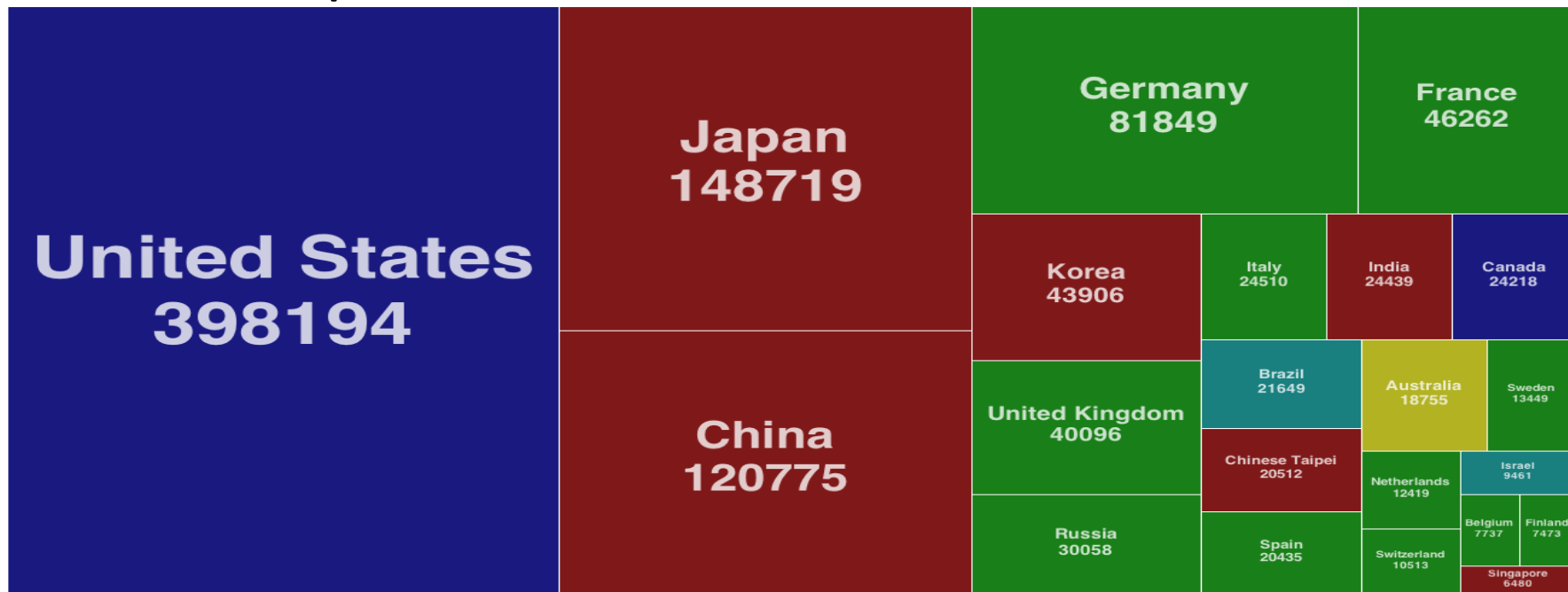
babynamewizard.com (via waitbutwhy.com)

Contour Plot



Treemaps

- Area represents attribute value:



Cartogram

- Fancier version of treemaps:



Stream Graph



Stream Graph

Baby Name >

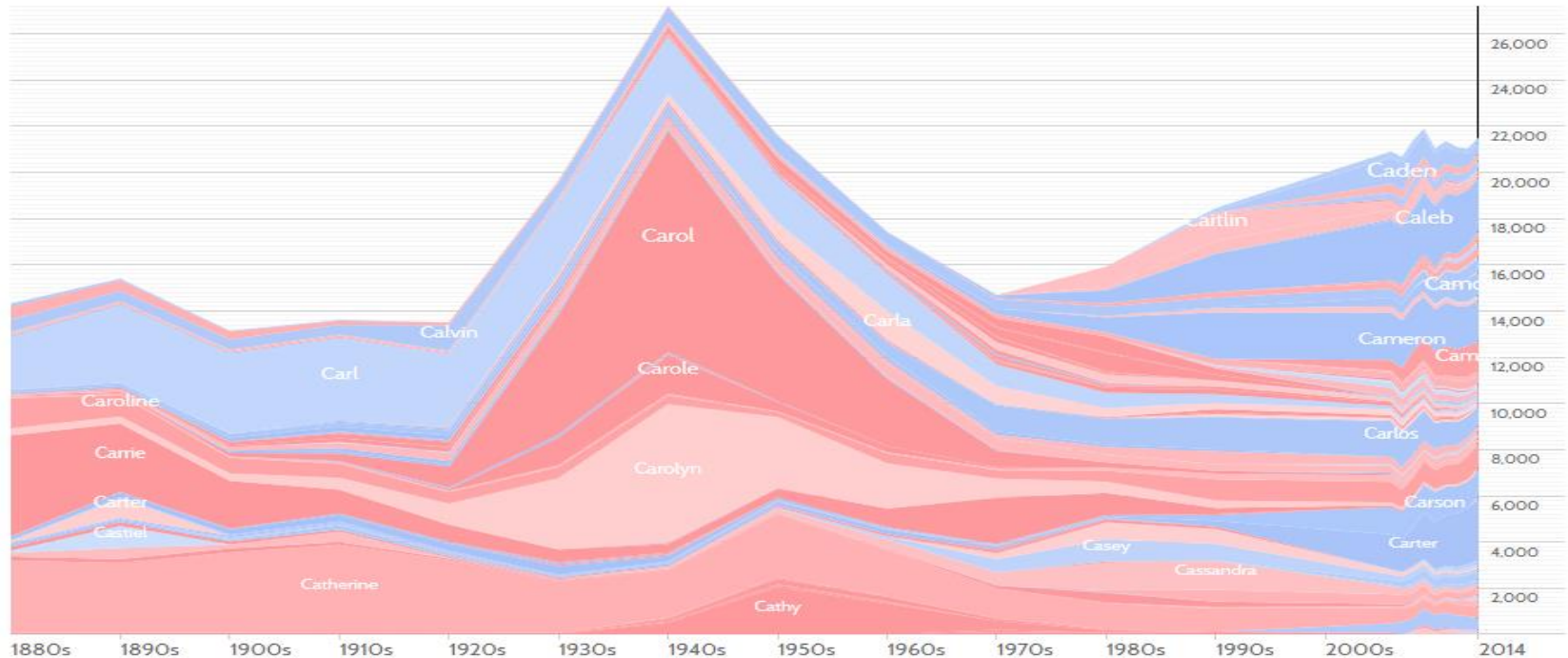
☒ Both ☐ Boys ☐ Girls

boys	1000	500	100	25	1
girls	1000	500	100	25	1

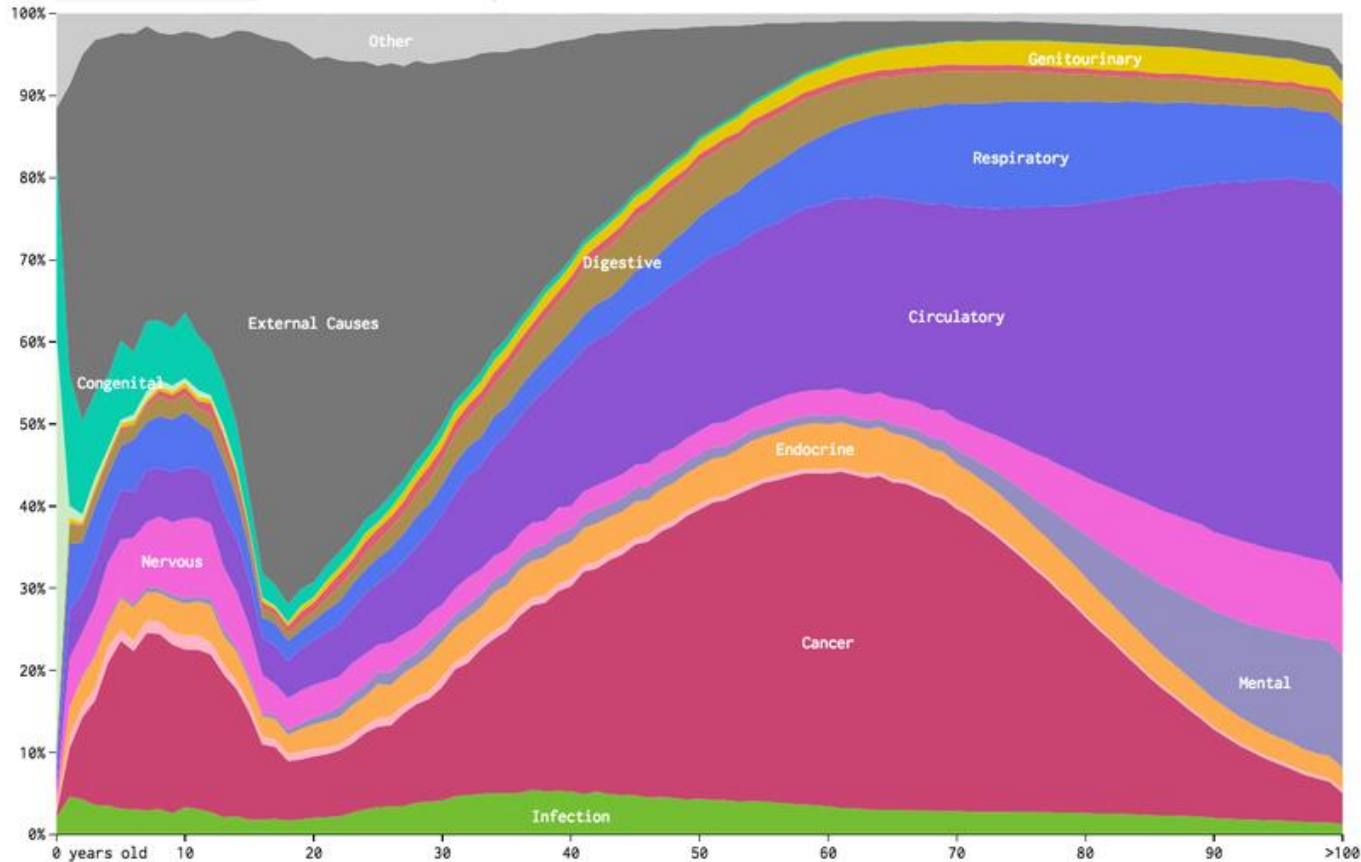
Current rank:

per million births

Names starting with 'CA' per million babies



Stream Graph



Summary

- Typical data mining steps:
 - Involves data collection, preprocessing, analysis, and evaluation.
- Object-feature representation and discrete/numerical features.
- Data preprocessing:
 - IID assumption, data cleaning, feature transformations.
- Exploring data:
 - Summary statistics and data visualization.
- Next week: let's start some machine learning...