Computational Analysis of Big Data

Week 2

A Data Scientist's most fundamental tools

More specifically: Visualization, linear algebra and statistics

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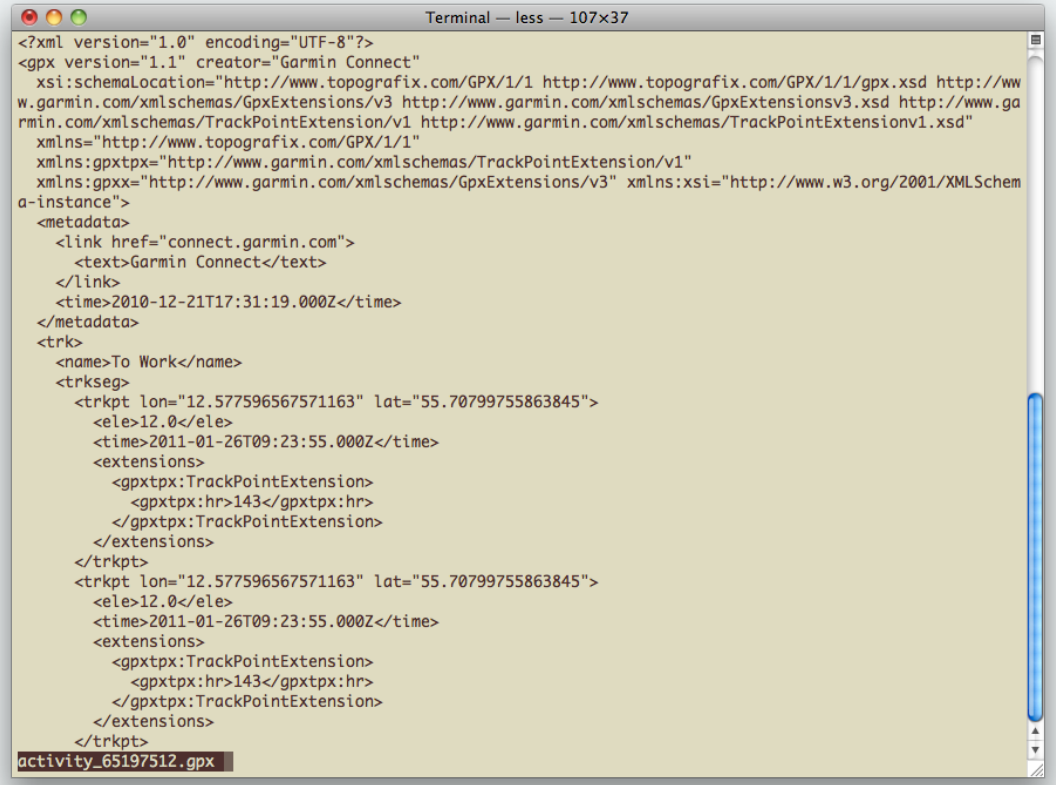
1000

1
1000

.

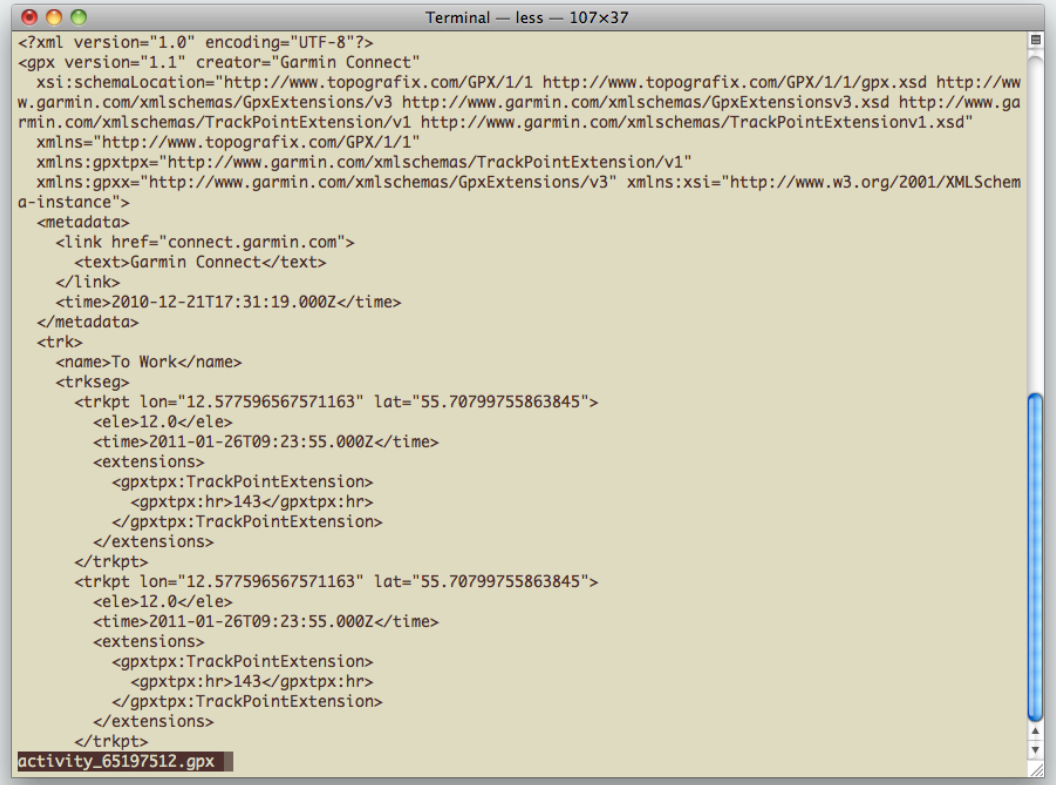
This is data

It's usually some (large) file full of text and numbers



This is GPS data

It's usually some (large) file full of text and numbers

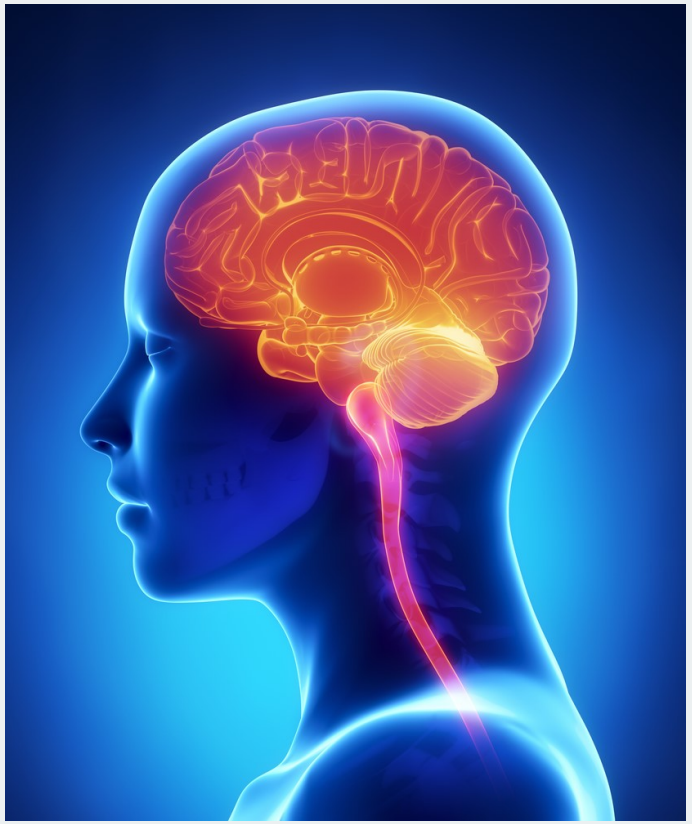


And if you're lucky there is also some kind of **<markup>**

Most raw data is incomprehensible to humans

We have:

- Narrow spectrum of data that we can process and understand
- Limited memory for processing new information
- Limited attention for undertaking focussed tasks

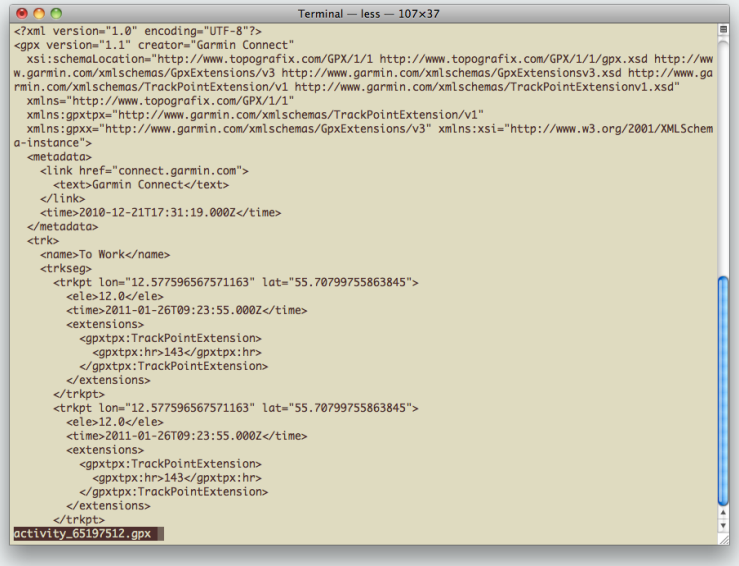


The human eye is made for advanced pattern recognition

It can:

- Immediately **recognize patterns** in highly complex images
- Notice **outliers**
- Process streams of images and recognize **patterns over time**

Data must be rendered in human-friendly format



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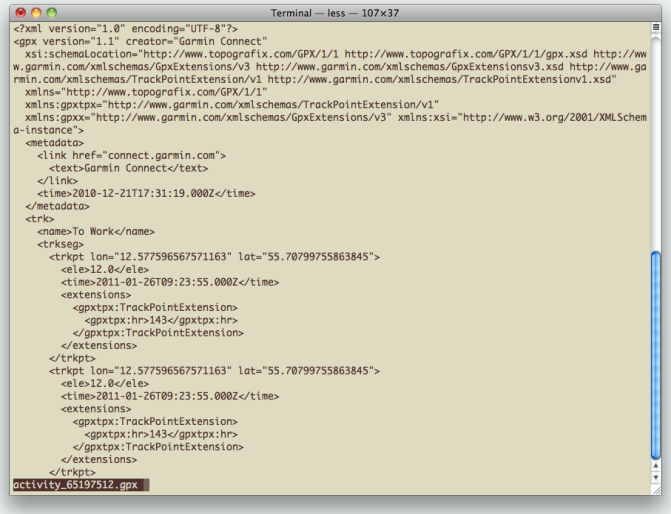

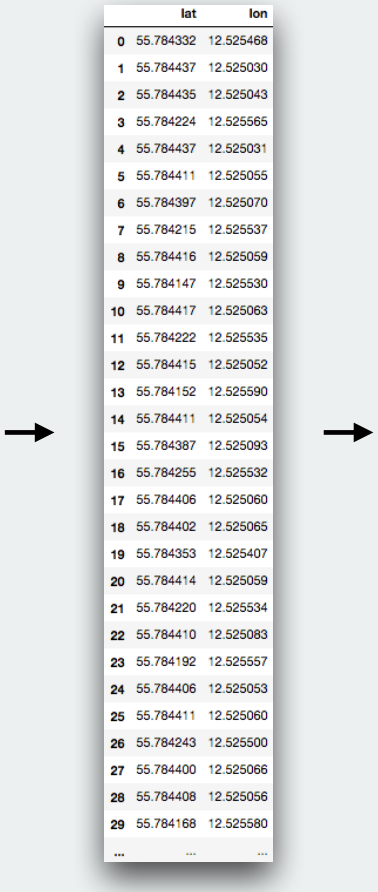

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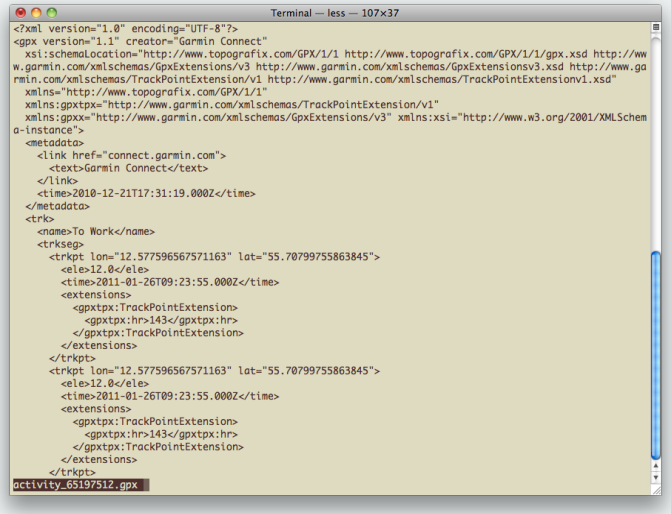

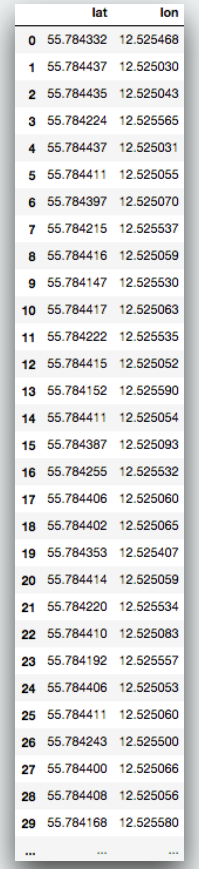

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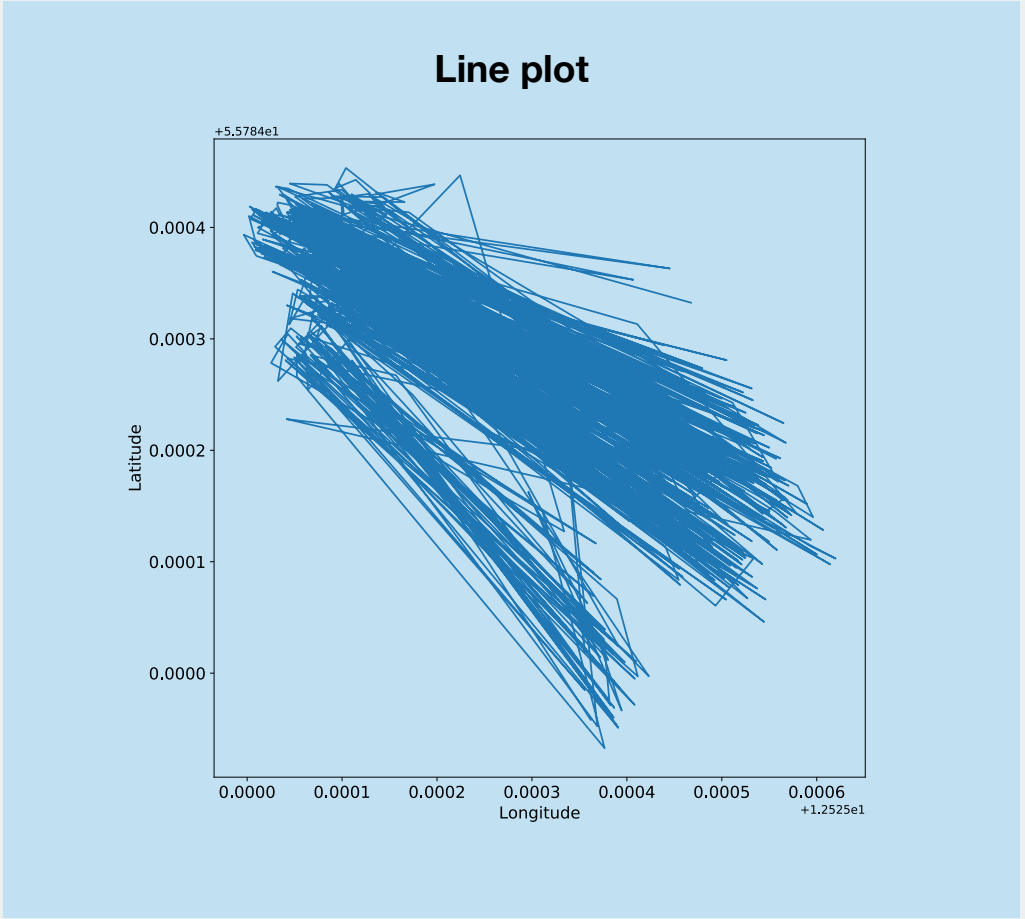

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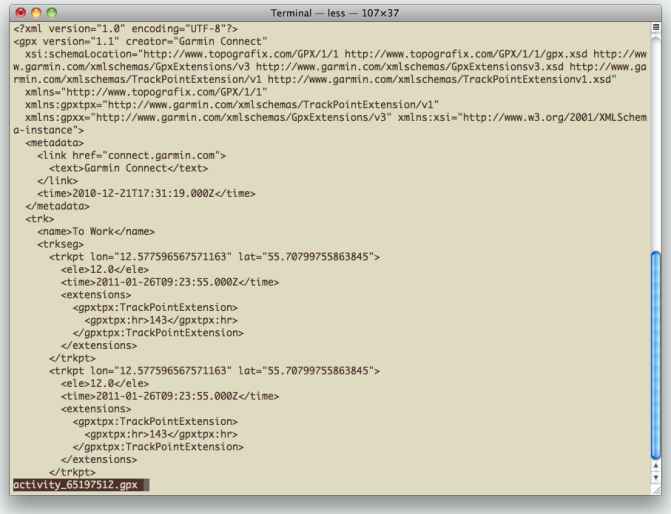

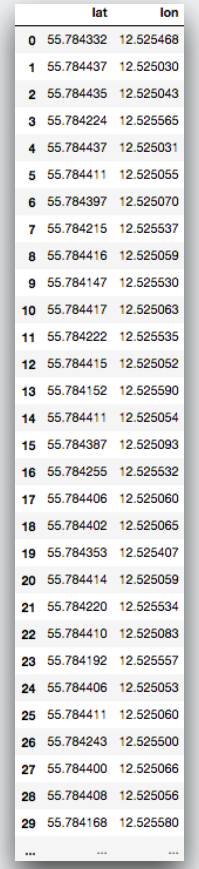

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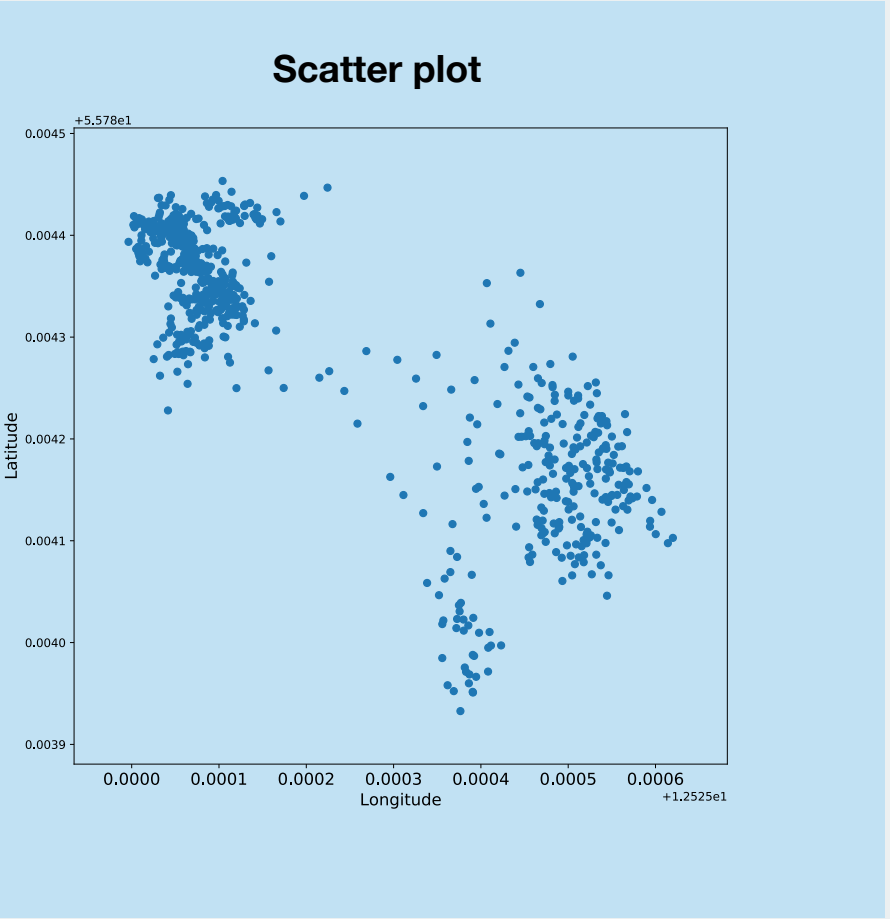

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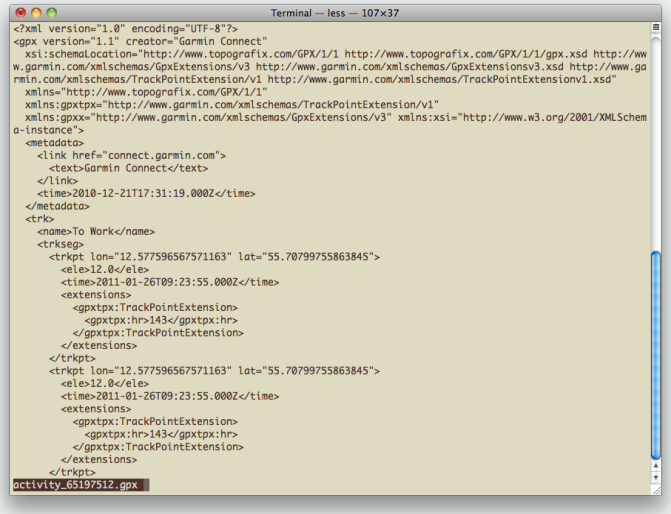

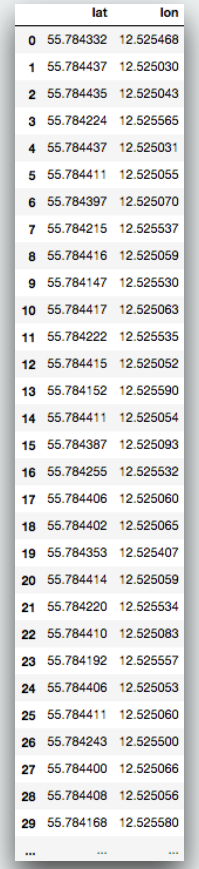

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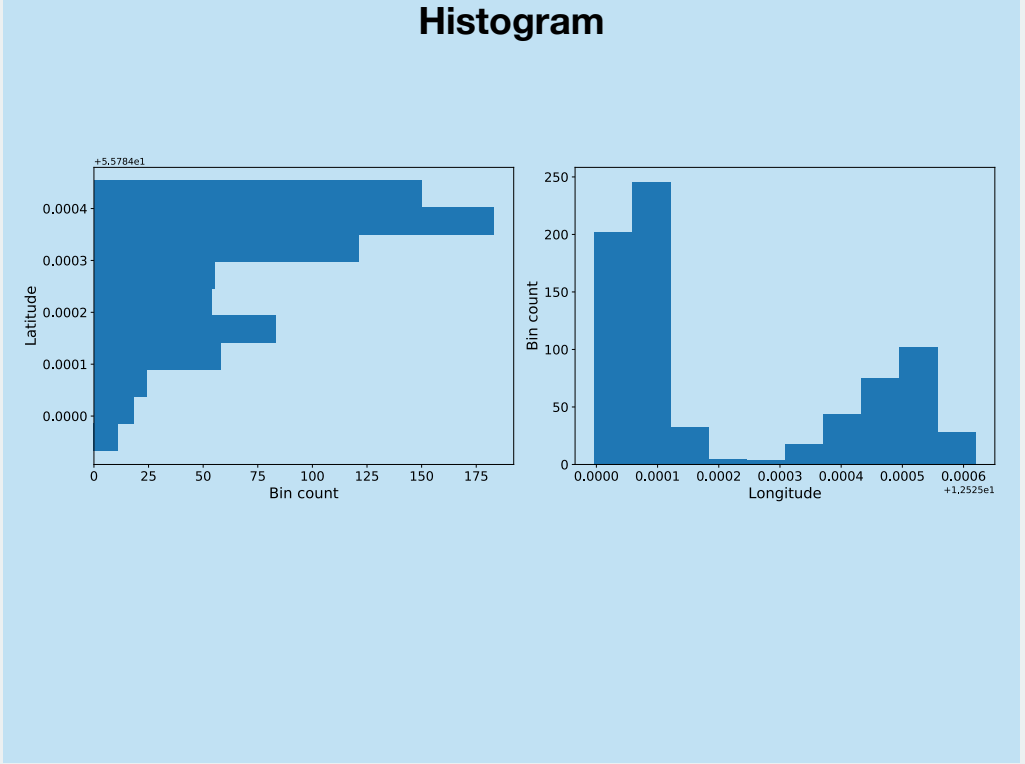

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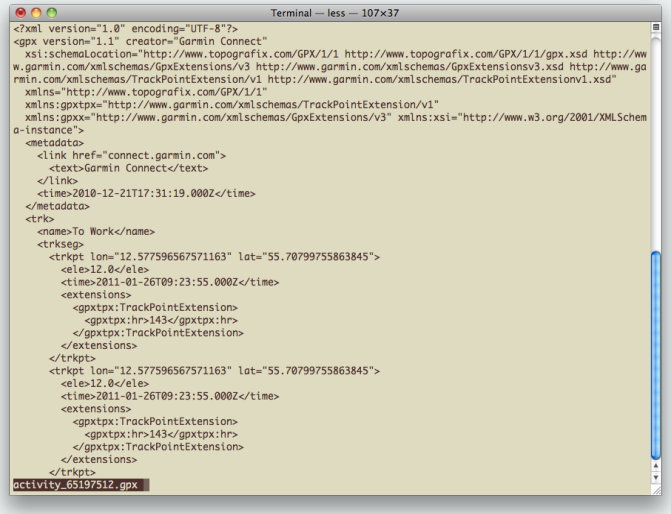

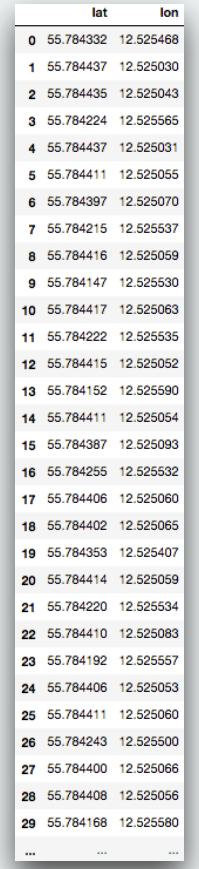

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Heatmap

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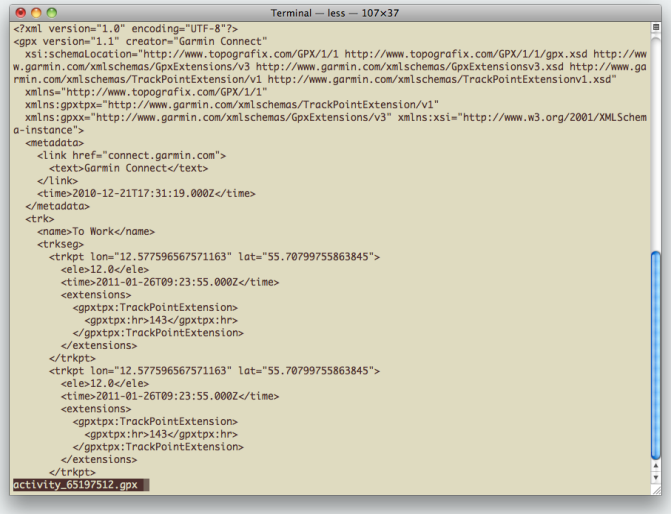

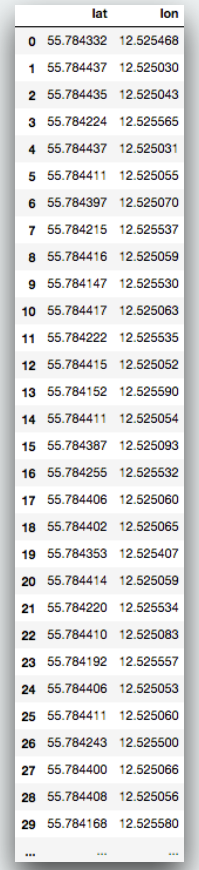

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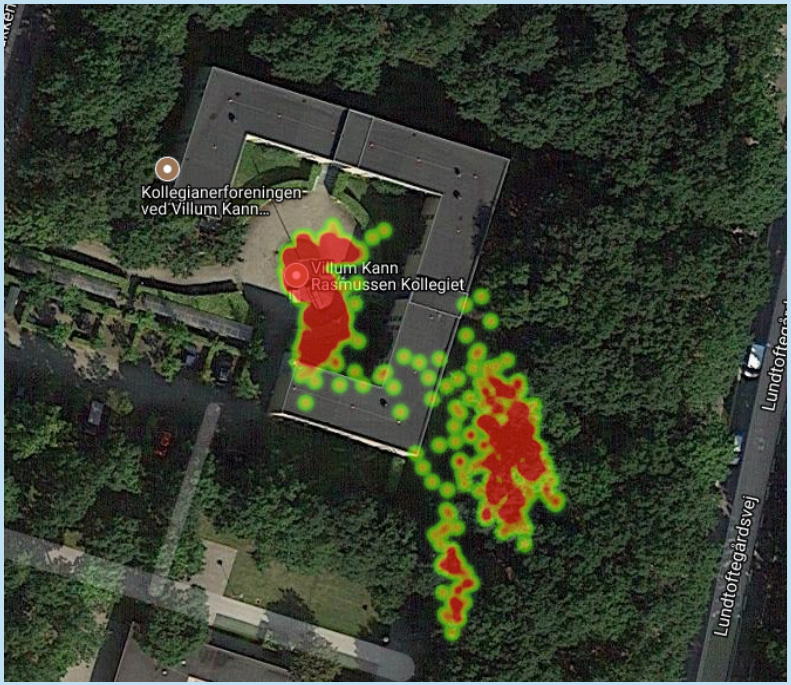
Heatmap



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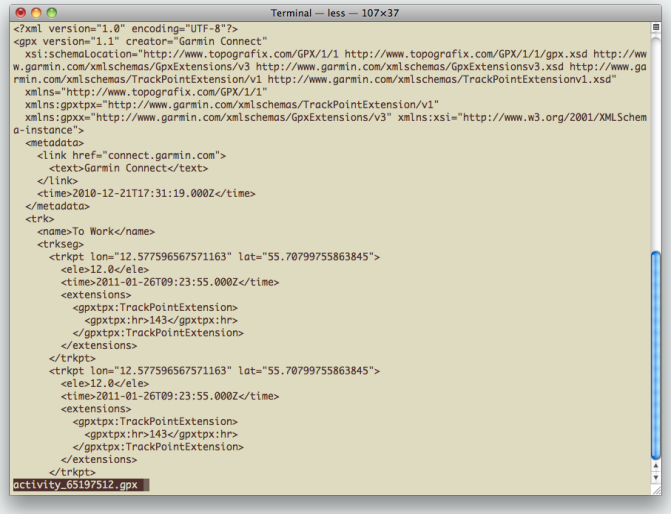

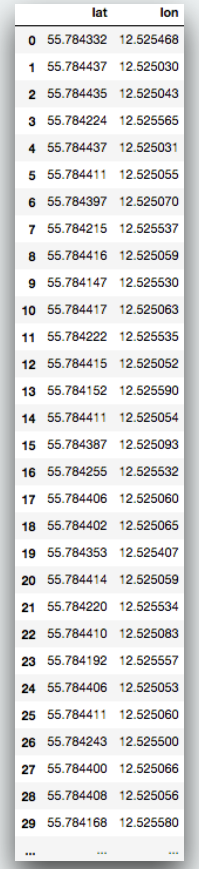

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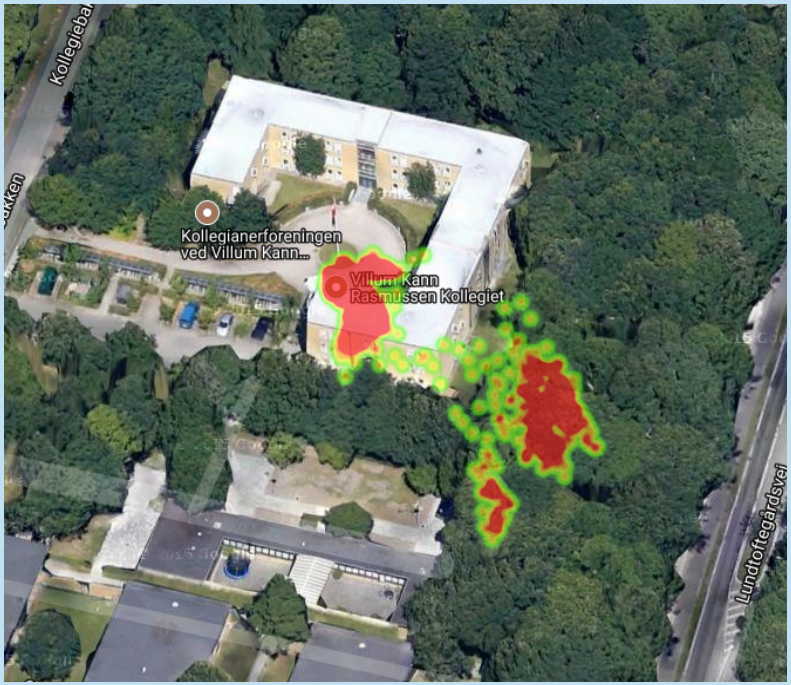
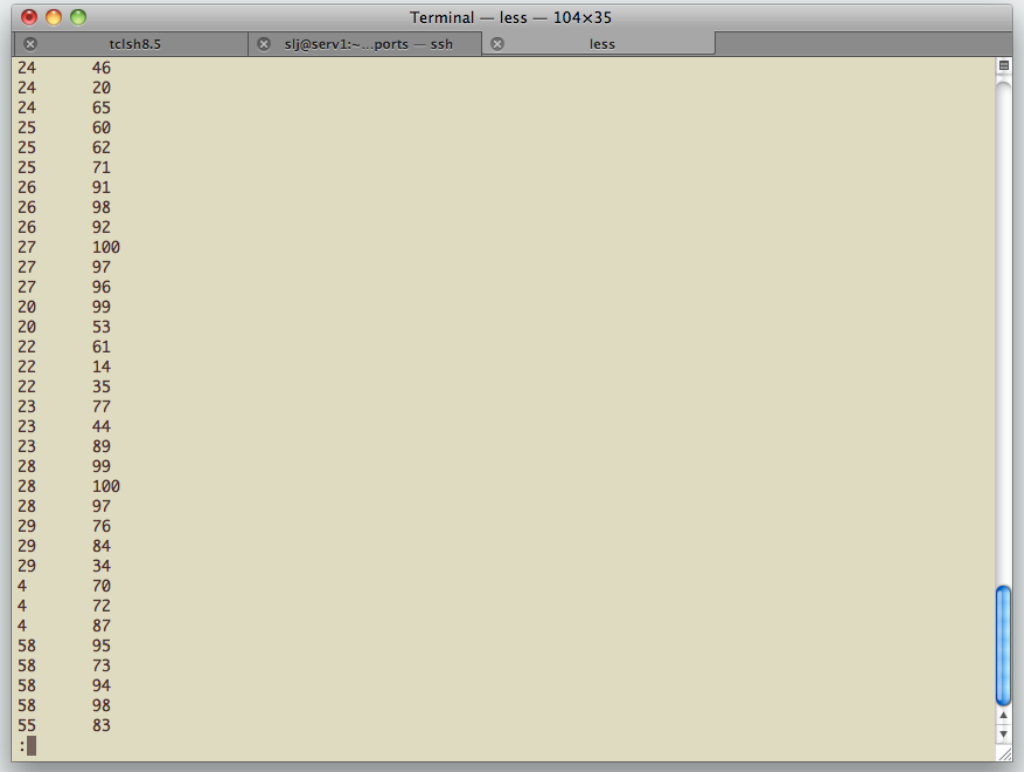


Relational data



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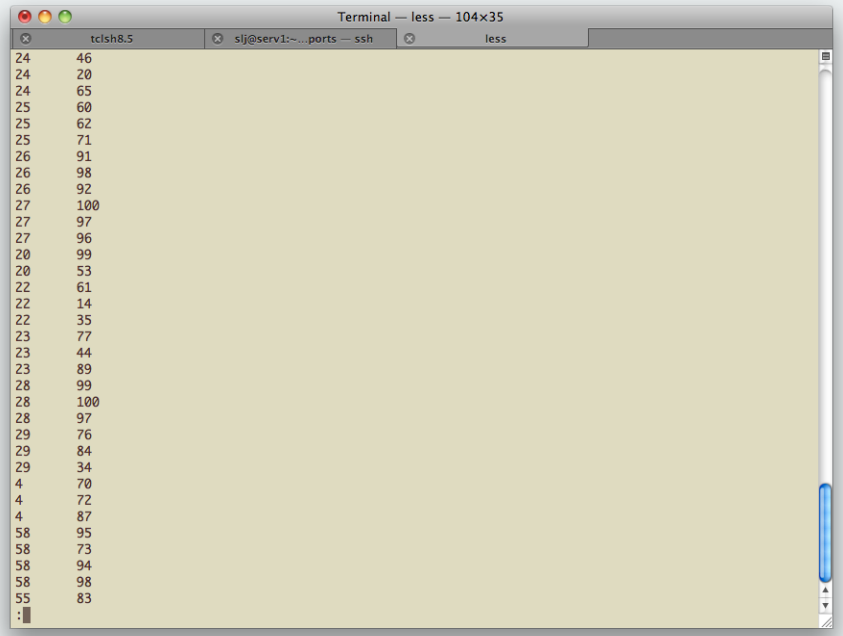

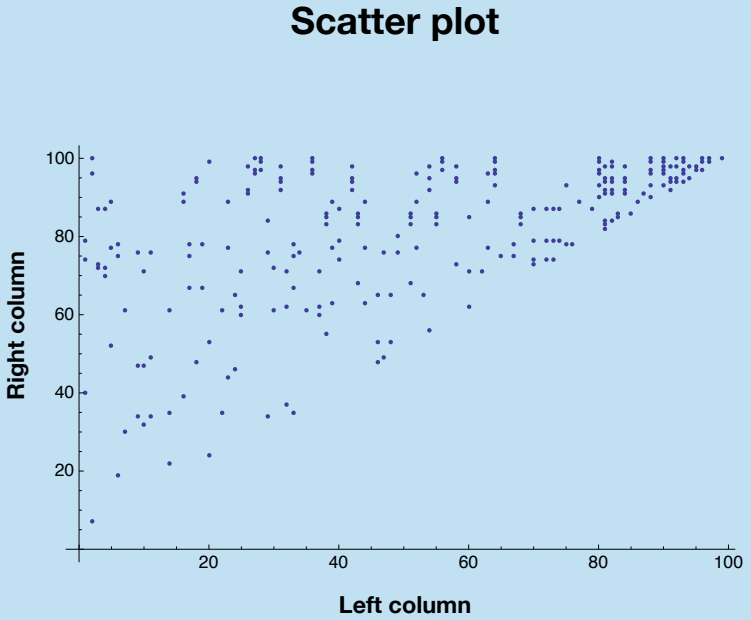

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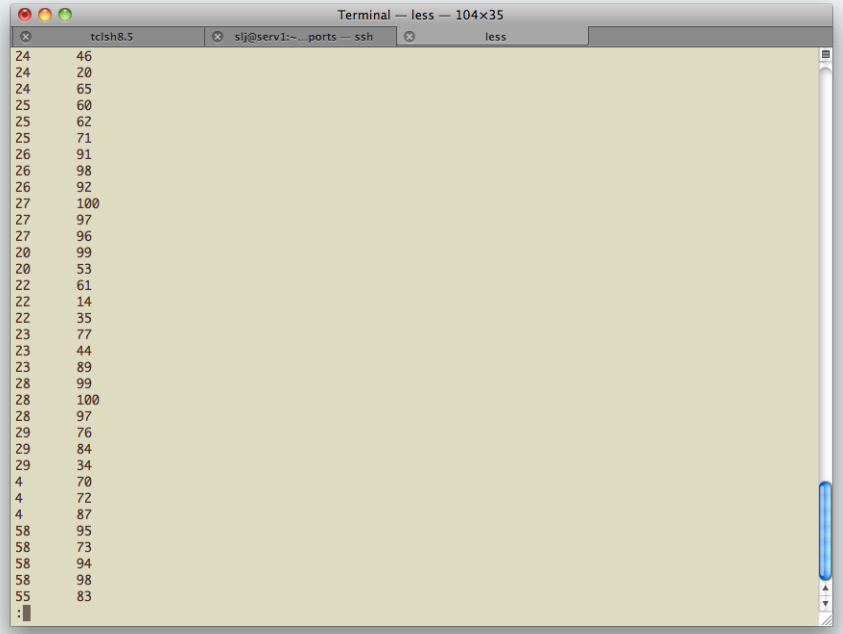

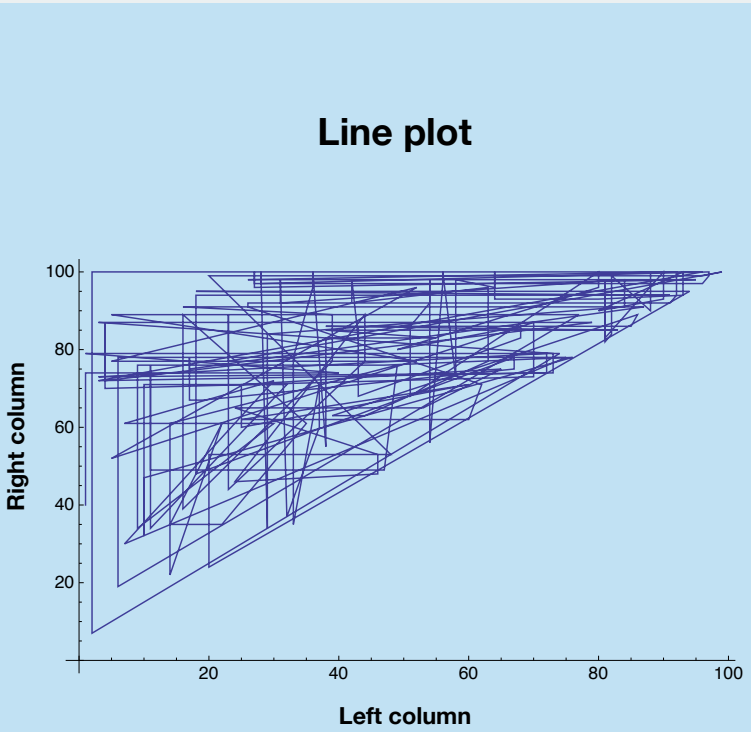

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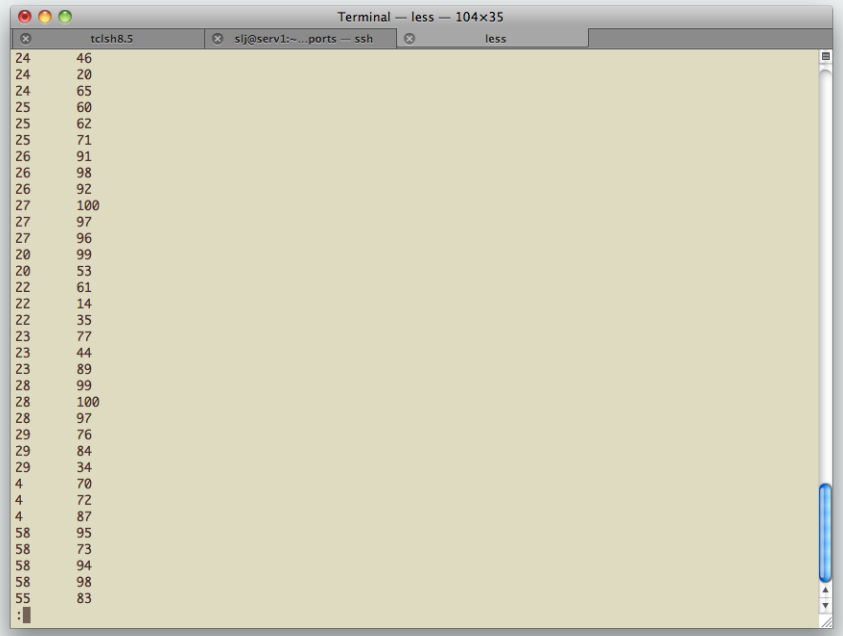
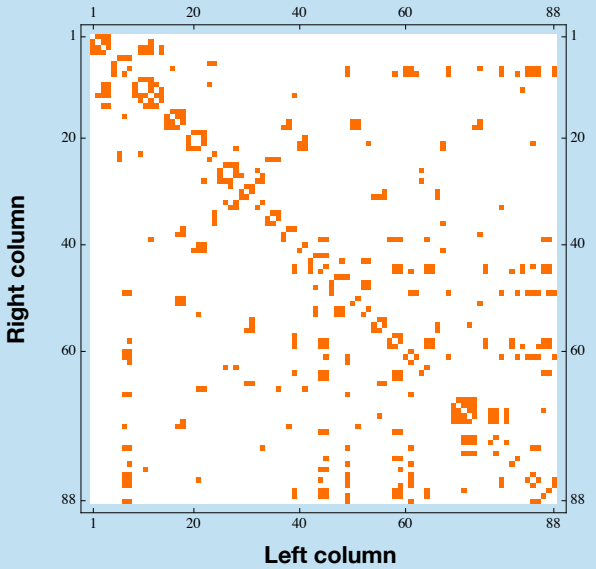
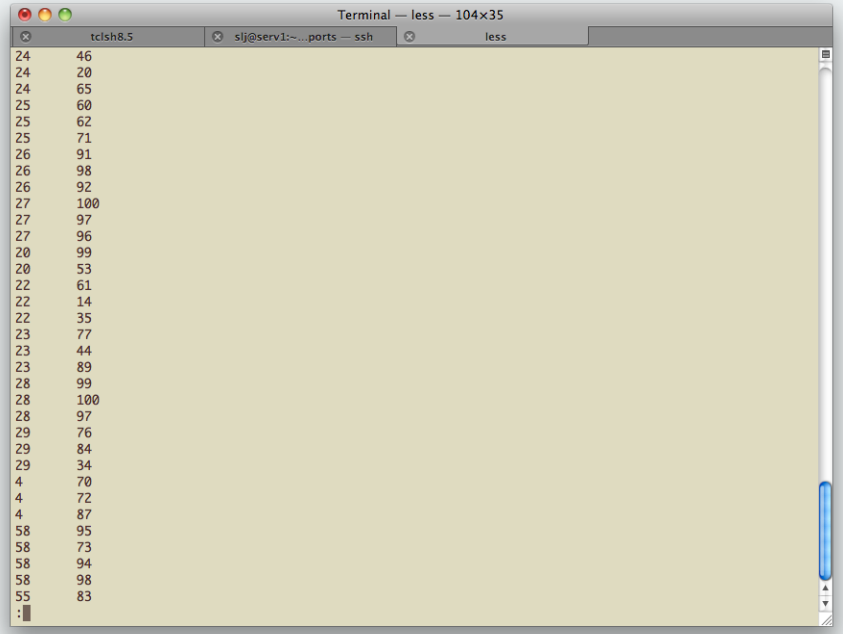
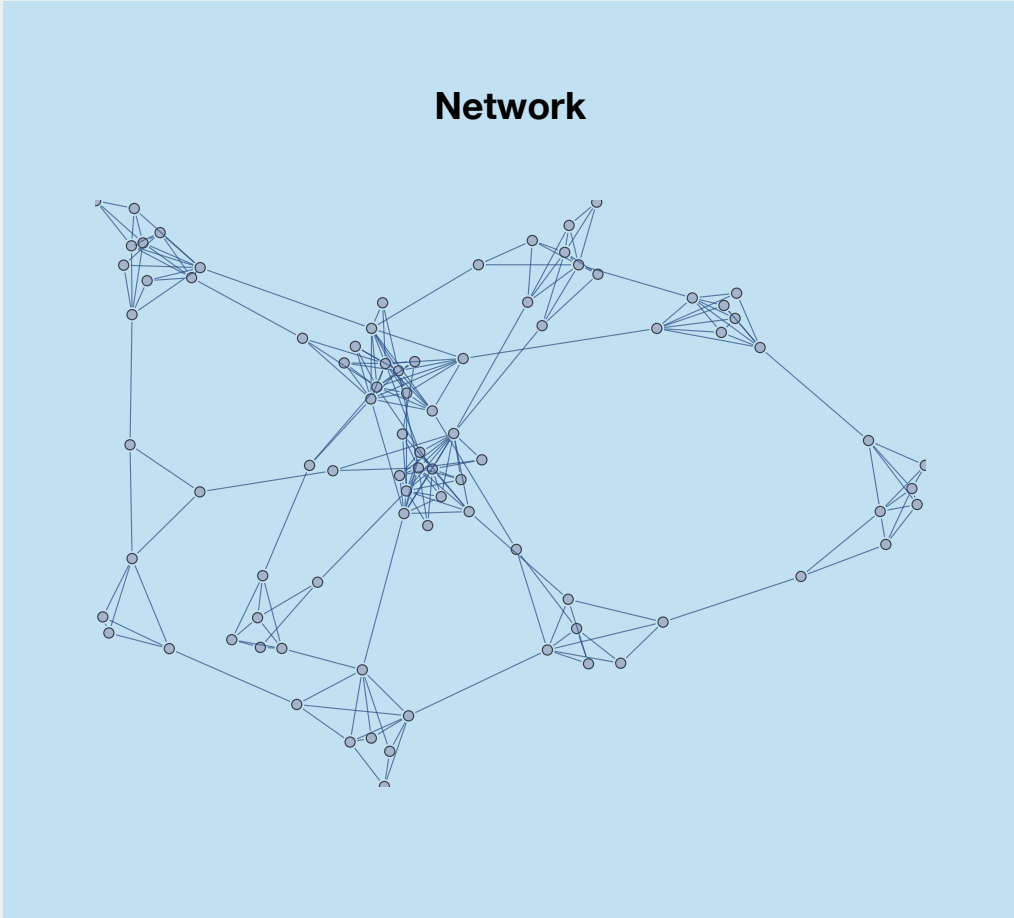


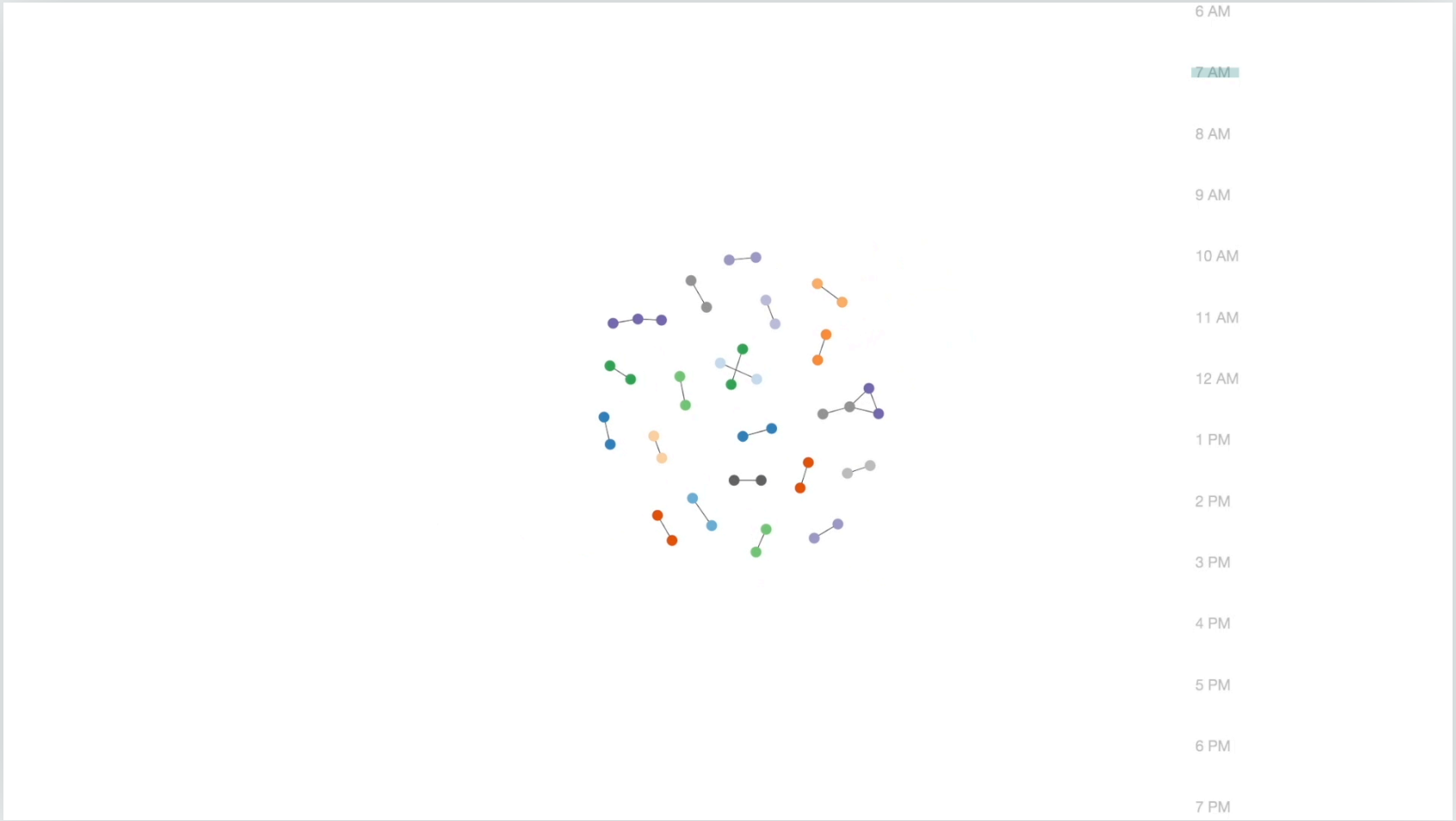


Relational data





Very complex data that changes in time!



link

link

Most fancy visualizations break down to very simple things

For understanding how data is **distributed**

- Histograms
- Kernel density plots
- Box plots/violin plots
- Heatmaps

Most fancy visualizations break down to very simple things

For understanding how data is **distributed**

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For understanding how variables in data **relate and develop**

- Scatter plots
- Pairs plot
- Time series plot
- Line plot
- Bar plot

Most fancy visualizations break down to very simple things

For understanding how data is **distributed**	• Histograms • Kernel density plots • Box plots/violin plots • Heatmaps
For understanding how variables in data **relate and develop**	• Scatter plots • Pairs plot • Time series plot • Line plot • Bar plot
For understanding **complex structure** in interconnected data	• Networks

Linear algebra

Linear algebra

Tools for manipulating tabular data

Linear algebra

Tools for manipulating tabular data

Objects

- Scalars
- Vectors
- Matrices

Everything is a Tensor!

Linear algebra

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Everything is a Tensor!

scalar

0D

```
In [2]: print np.random.randint(1, 100)
Last executed 2018-01-25 11:52:52 in 5ms
82
```

Linear algebra

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In [2]: print np.random.randint(1, 100)
Last executed 2018-01-25 11:52:52 in 5ms
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vector

1D

```
In [3]: print np.random.randint(1, 100, size=3)
Last executed 2018-01-25 11:53:37 in 5ms
[83 80 84]
```

Linear algebra

Tools for manipulating tabular data

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matrix

2D

```
In [4]: print np.random.randint(1, 100, size=(3, 3))
Last executed 2018-01-25 11:54:38 in 4ms
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 [15 82  9]
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```

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Last executed 2018-01-25 11:54:38 in 4ms
[[99 47 77]
 [15 82  9]
 [59 55 48]]
```

3D–tensor

3D

```
In [5]: print np.random.randint(1, 100, size=(3, 3, 3))
Last executed 2018-01-25 11:55:19 in 5ms
[[[45 11 73]
  [84 50 88]
  [13 22 97]]

 [[10  5 12]
  [27 23 76]
  [43 84 53]]

 [[86 58 61]
  [71 95 86]
  [92 19 68]]]
```

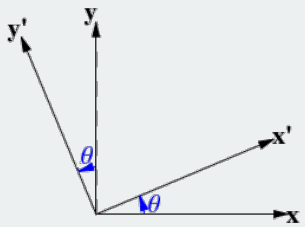
Linear algebra

Tools for manipulating tabular data

Operations

- Products: ***dot***, *cross*
- Elementwise: *addition*, *subtraction*, *multiplication*, *division*
- Mutations: *transpose*, *inverse/pseudo-inverse*, *scaling*, *rotation*

$$\begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} ax + by + cz \\ dx + ey + fz \\ gx + hy + iz \end{bmatrix}$$



used frequently for basis transformation

Linear algebra

Tools for manipulating tabular data

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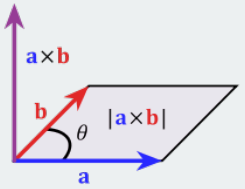

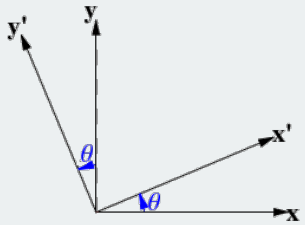

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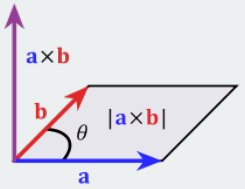
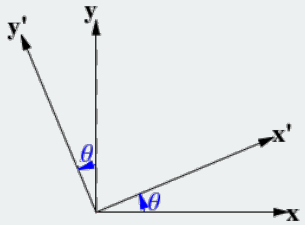




used frequently for basis transformation

$$\begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix}$$ Original matrix

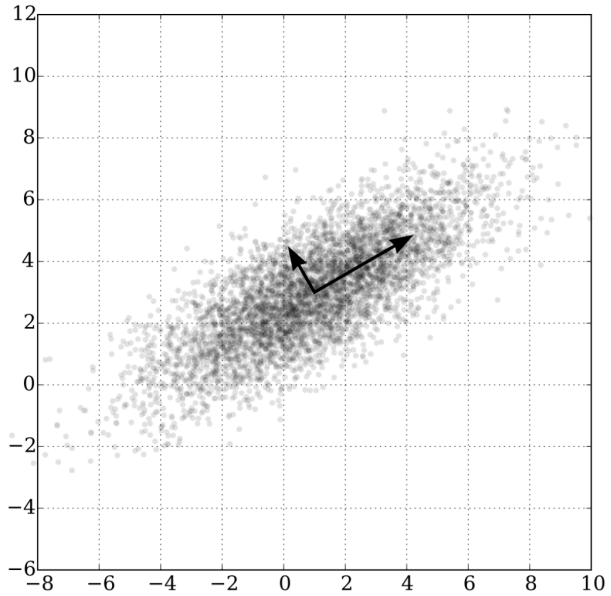
$$\begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix}^T \Rightarrow \begin{bmatrix} a & d & g \\ b & e & h \\ c & f & i \end{bmatrix}$$

Linear algebra

Tools for manipulating tabular data

Tools

- **Principal Component Analysis (PCA)**
- Archetypal Analysis
- Non-negative matrix factorization
- … many more

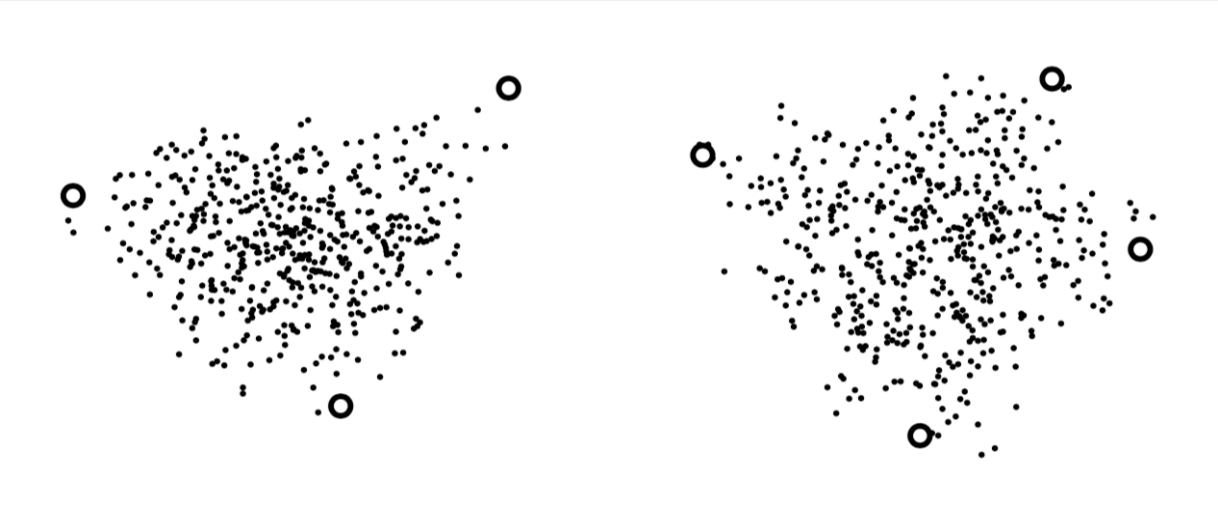


Linear algebra

Tools for manipulating tabular data

Tools

- Principal Component Analysis (PCA)
- **Archetypal Analysis**
- Non-negative matrix factorization
- … many more



Linear algebra

Tools for manipulating tabular data

Tools

- Principal Component Analysis (PCA)
- Archetypal Analysis
- **Non-negative matrix factorization**
- … many more

Statistics

Statistics

Framework for describing data

Statistics

Framework for describing data

Vocabulary

- Mean, median
- Variance, standard deviation, range
- Correlation, covariance

Statistics

Framework for describing data

Vocabulary

- Mean, median
- Variance, standard deviation, range
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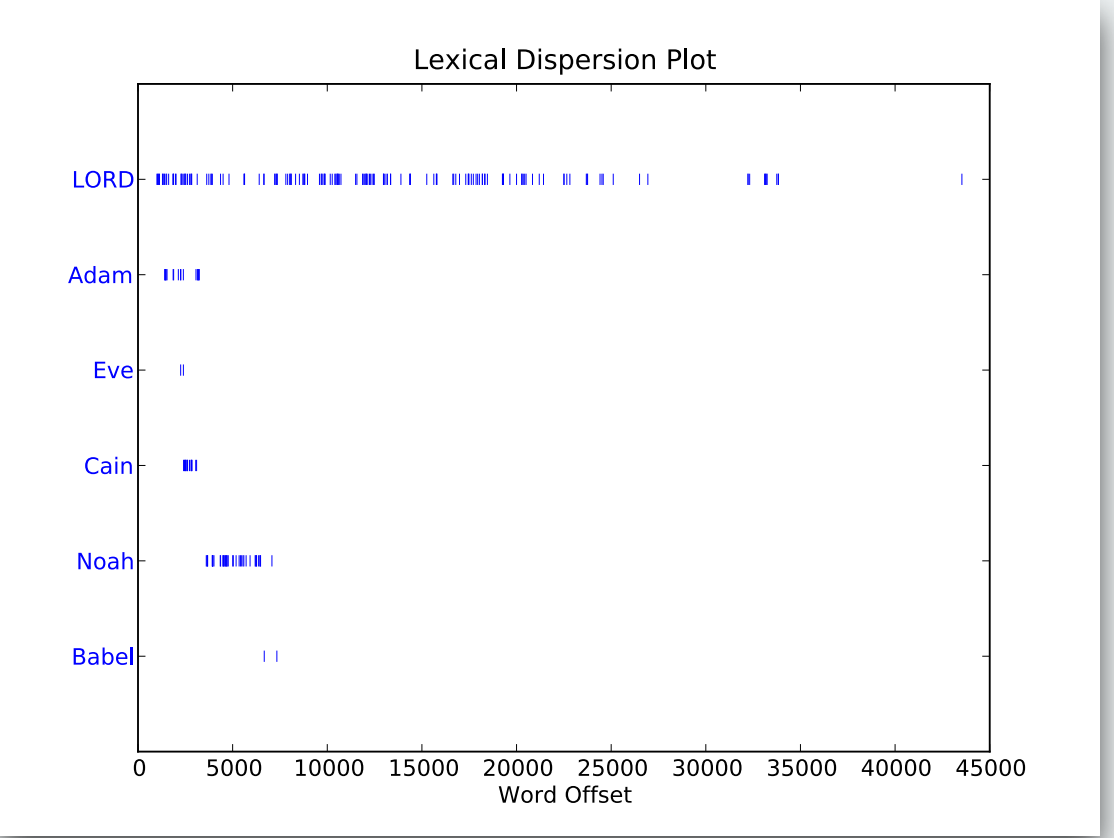


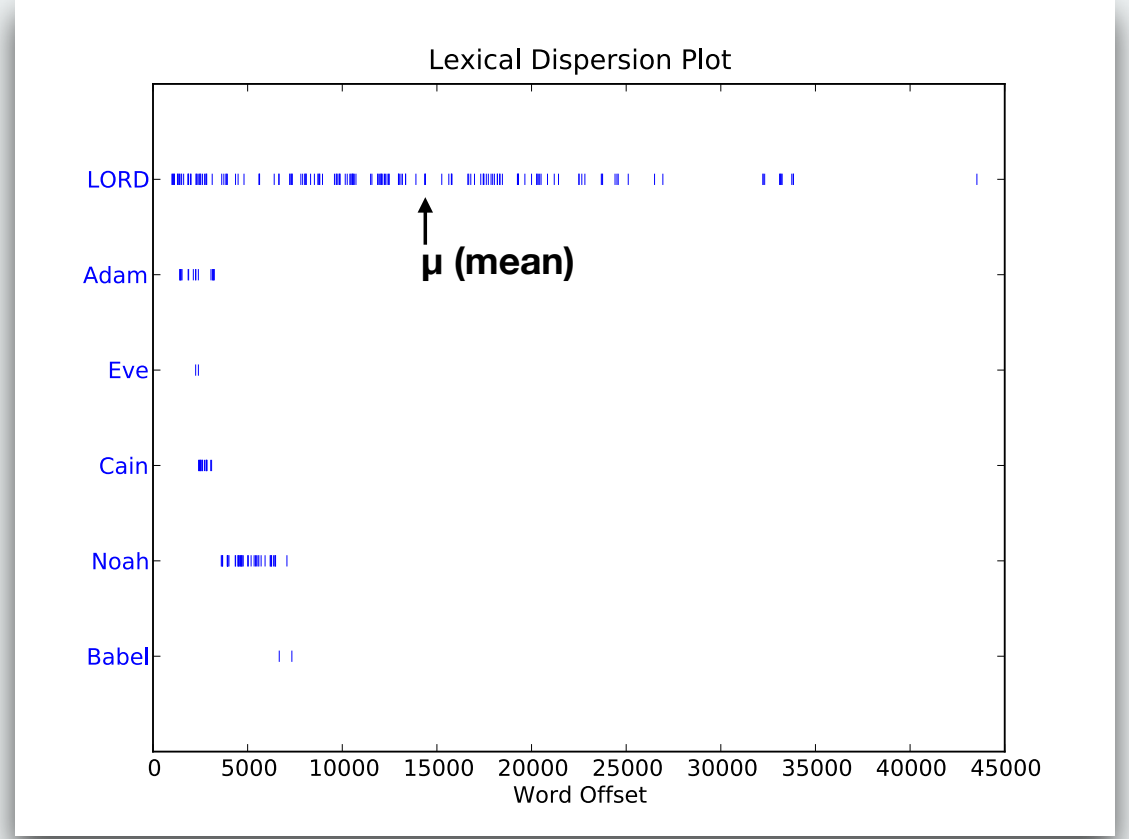
Statistics

Framework for describing data

Vocabulary

- **Mean**, median
- Variance, standard deviation, range
- Correlation, covariance

$$\mu = \frac{\text{Sum of values}}{\text{Number of values}}$$



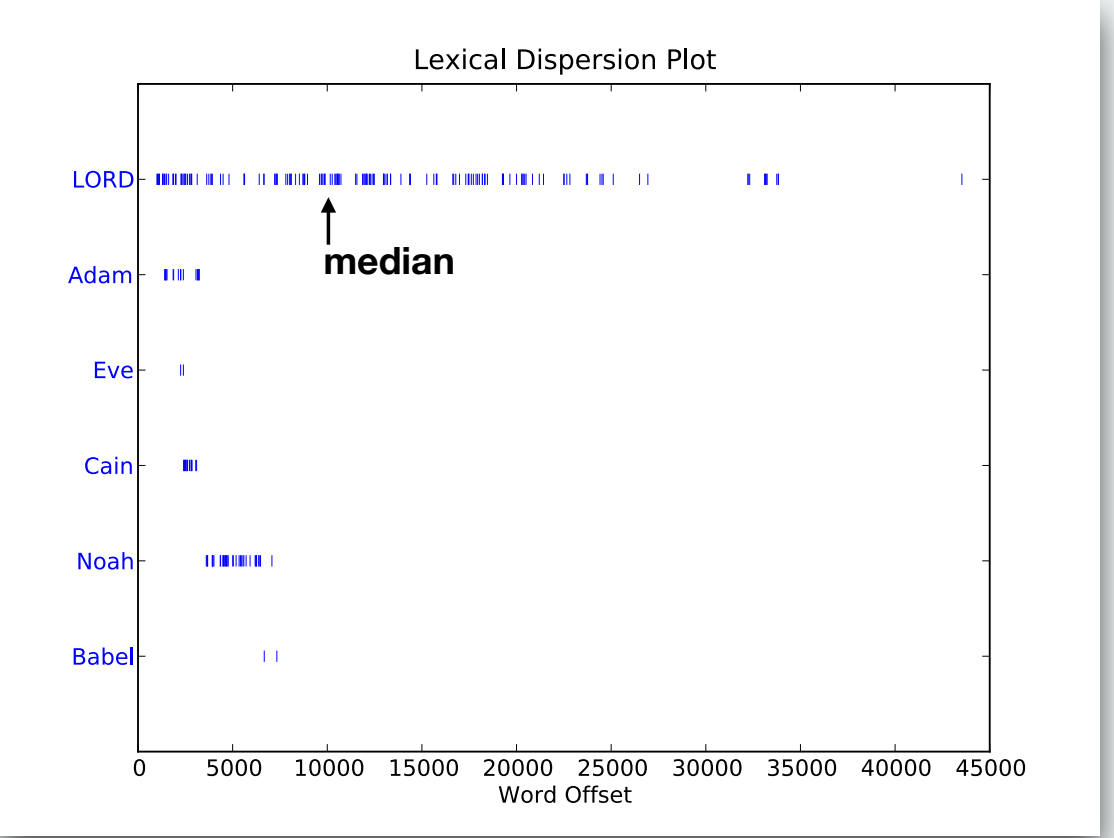
Statistics

Framework for describing data

Vocabulary

- Mean, **median**
- Variance, standard deviation, range
- Correlation, covariance

median = **Middle number in ordered list**



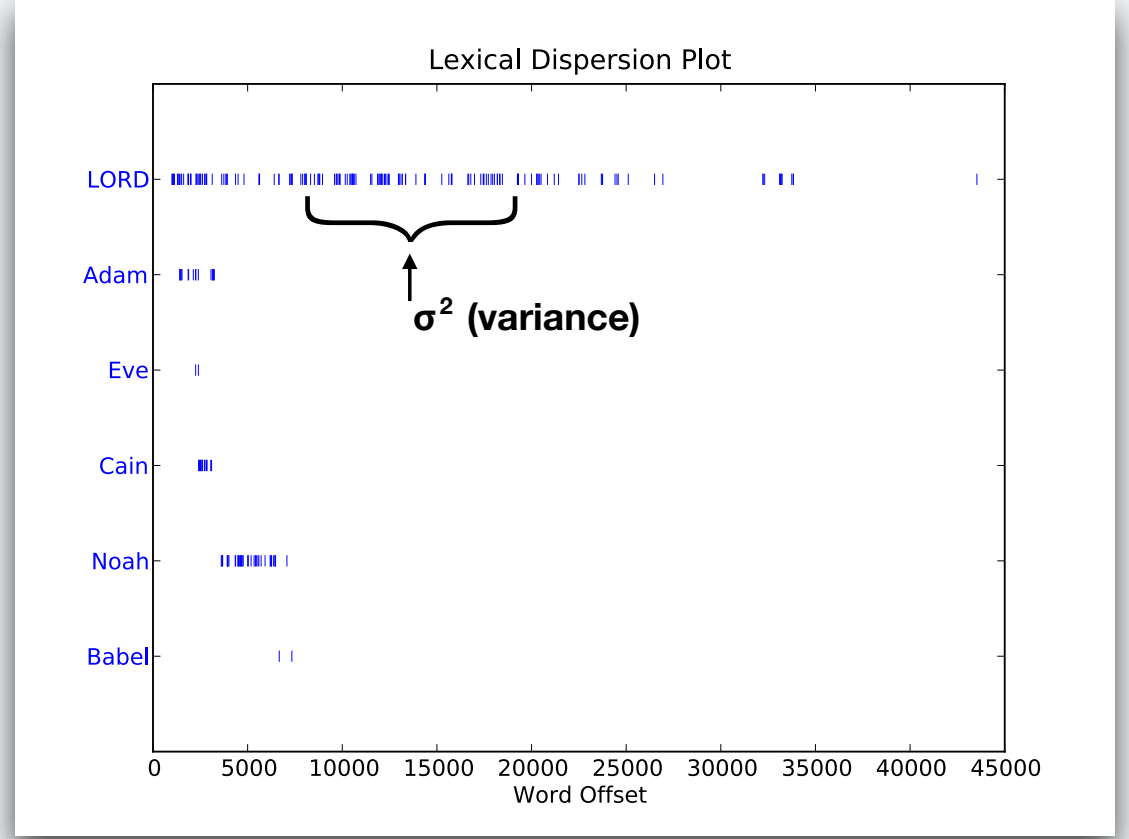
Statistics

Framework for describing data

Vocabulary

- Mean, median
- **Variance**, standard deviation, range
- Correlation, covariance

$$\sigma^2 = \frac{1}{N-1}\sum_{i=1}^{n}(x_i - \mu)^2$$



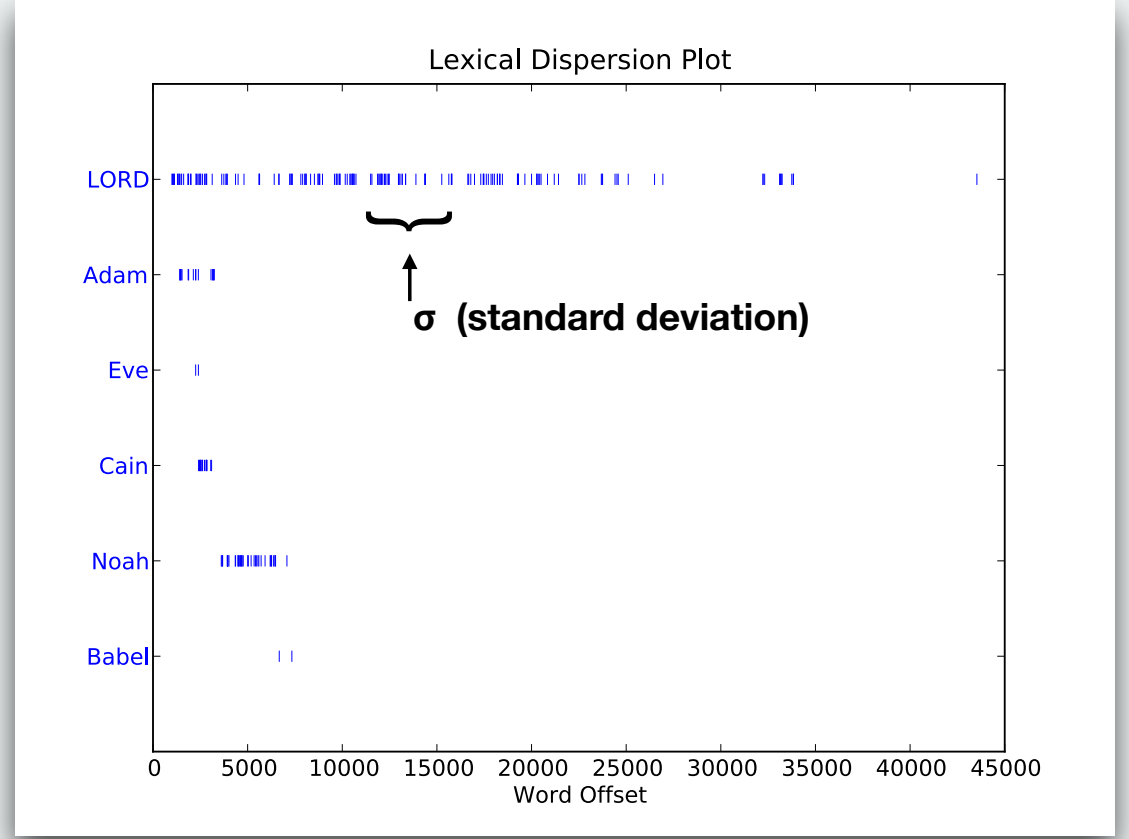
Statistics

Framework for describing data

Vocabulary

- Mean, median
- Variance, **standard deviation**, range
- Correlation, covariance

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{n}(x_i - \mu)^2}$$



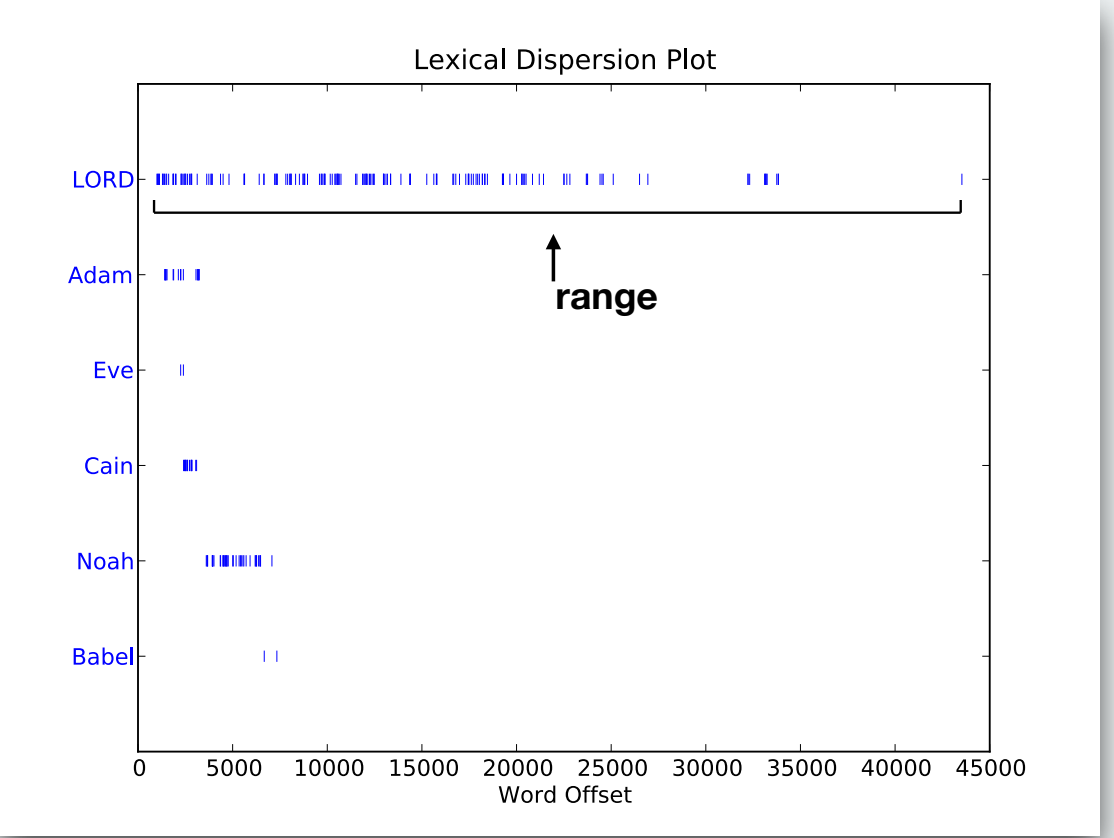
Statistics

Framework for describing data

Vocabulary

- Mean, median
- Variance, standard deviation, **range**
- Correlation, covariance

range = max(value) - min(value)



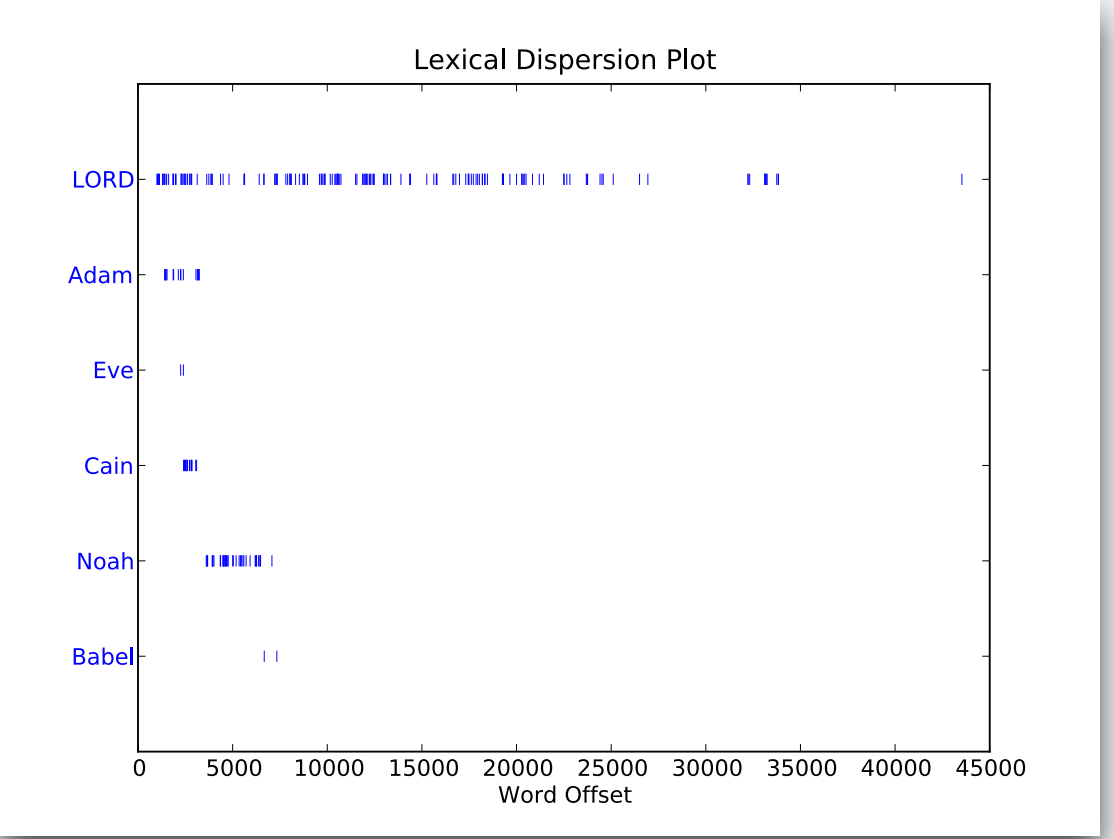
Statistics

Framework for describing data

Vocabulary

- Mean, median
- Variance, standard deviation, range
- Correlation, **covariance**

cov(X, Y) = $\frac{1}{n}\sum_{i=1}^{n}(x_i - \mu_X)(y_i - \mu_y)$



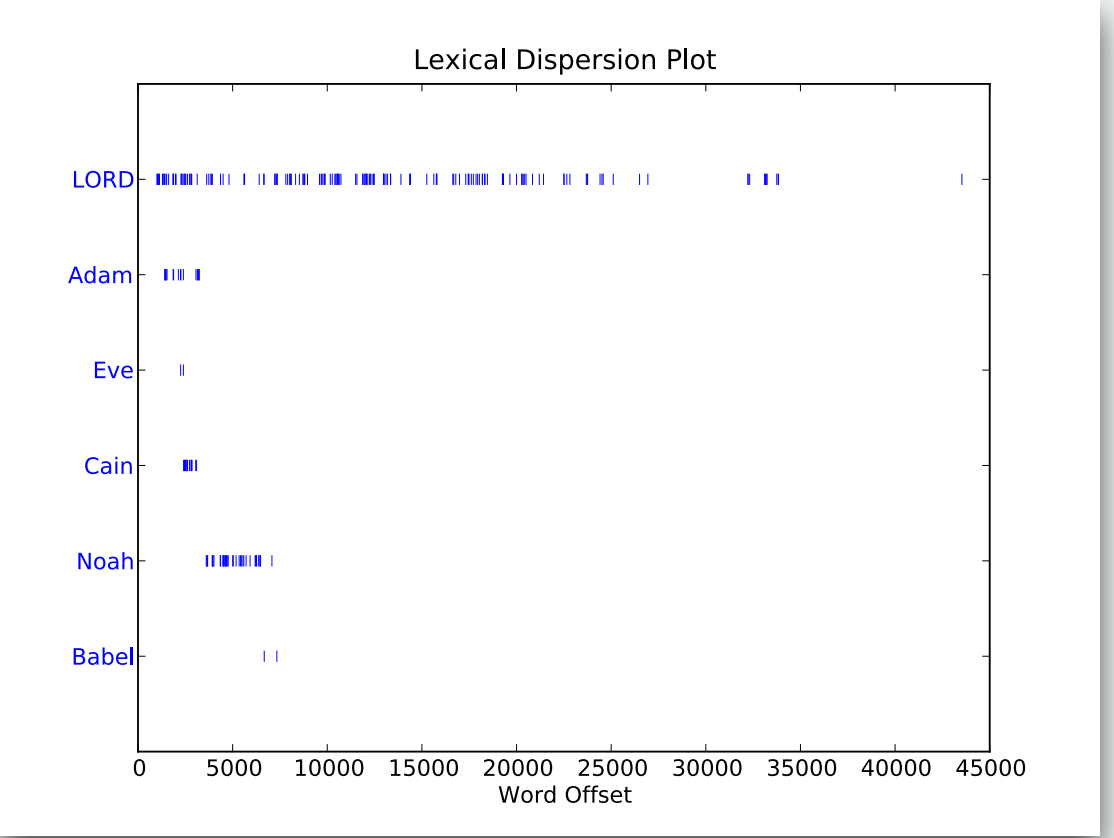
Statistics

Framework for describing data

Vocabulary

- Mean, median
- Variance, standard deviation, range
- **Correlation**, covariance

$$\textbf{cor(X, Y)} = \frac{cov(X, Y)}{\sigma_X \sigma_Y}$$

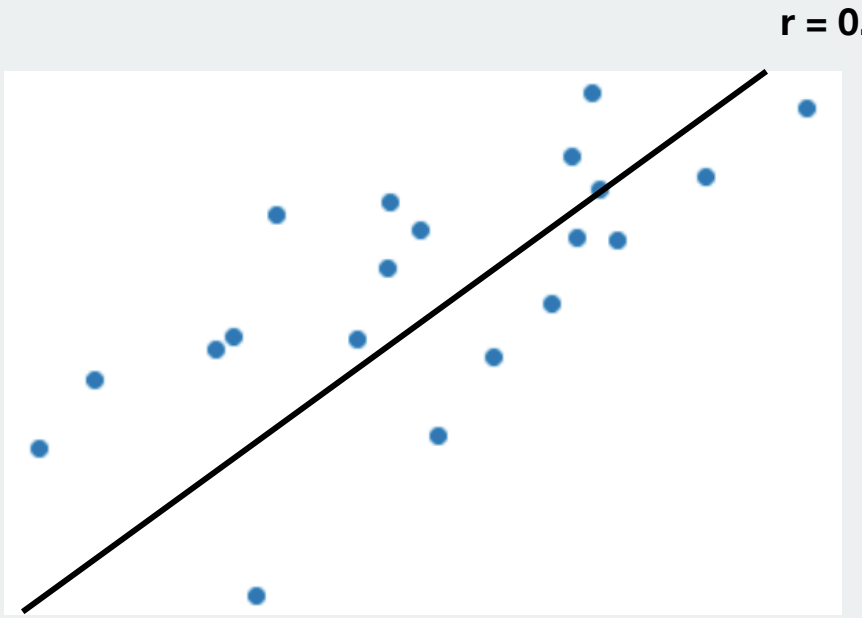


Statistics

Framework for describing data

Tools

- Hypothesis testing



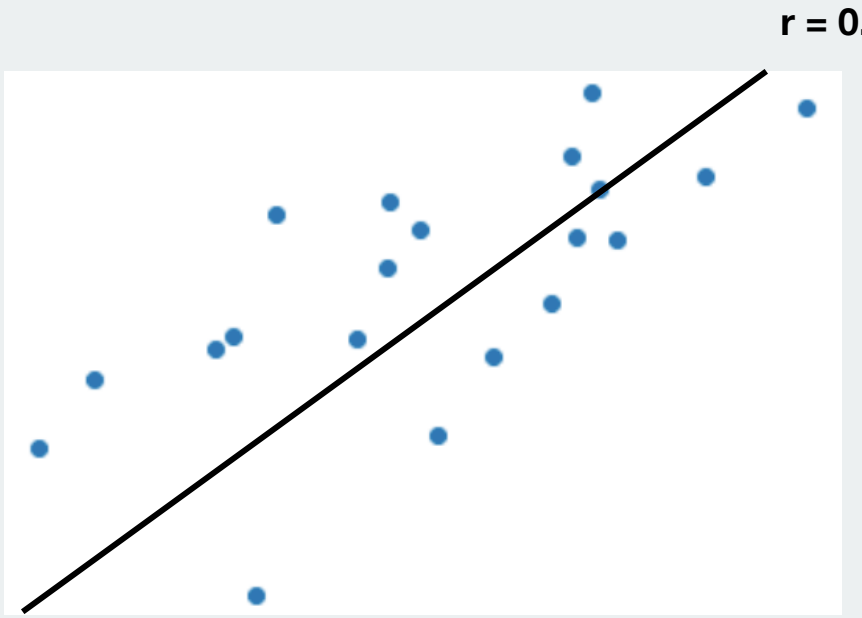
Statistics

Framework for describing data

Tools

- Hypothesis testing

Null hypothesis



Statistics

Tools

- Hypothesis testing

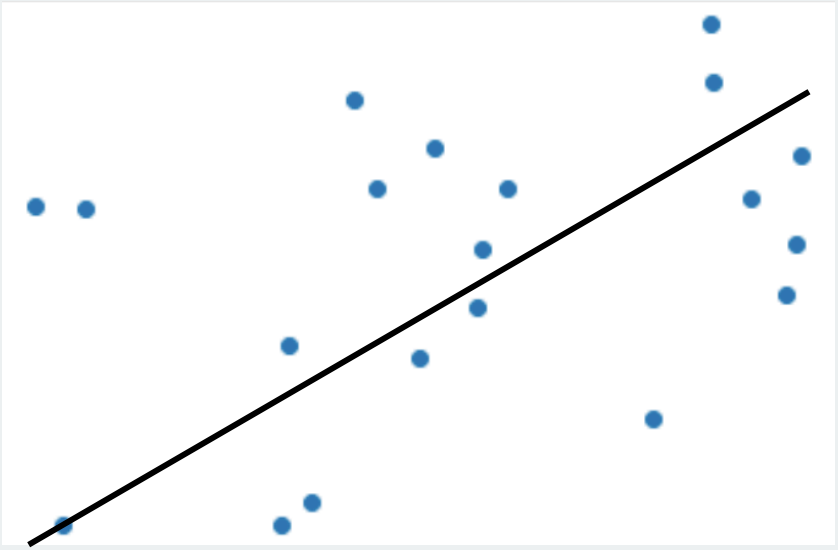
r = 0.2? But this is just one example. Still could be random

Null hypothesis

Framework for describing data

Null model

Randomization 1



r = 0.2

Statistics

Tools

- Hypothesis testing

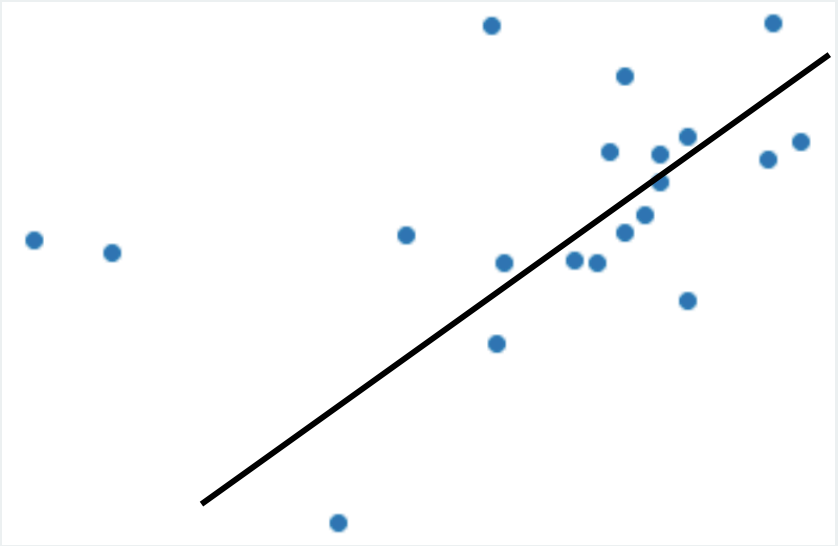
r = 0.25? Pure chance, I still think your r=0.6 is random

Null hypothesis

Framework for describing data

Null model

Randomization 2



r = 0.25

Statistics

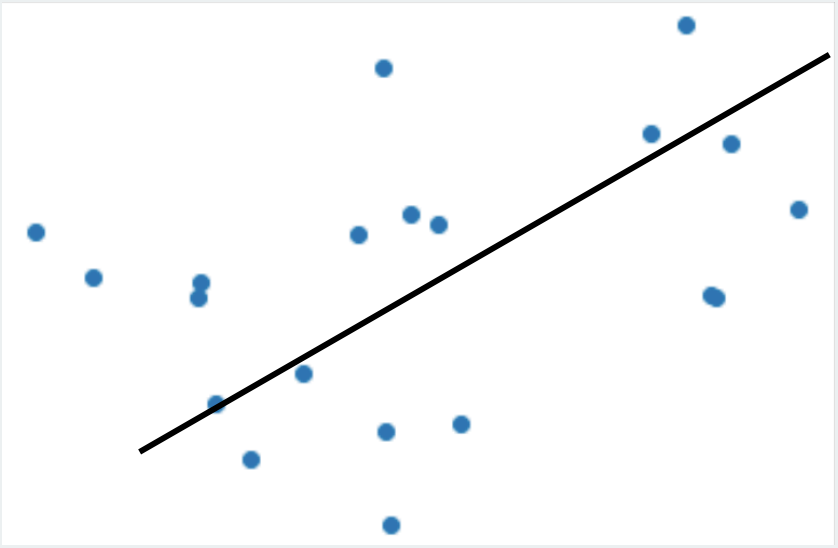
Tools

- Hypothesis testing

Framework for describing data

Null model

Randomization 1000



r = 0.3

REJECTED