Computational Analysis of Big Data

Week 2

A Data Scientist's most fundamental tools

Data visualization

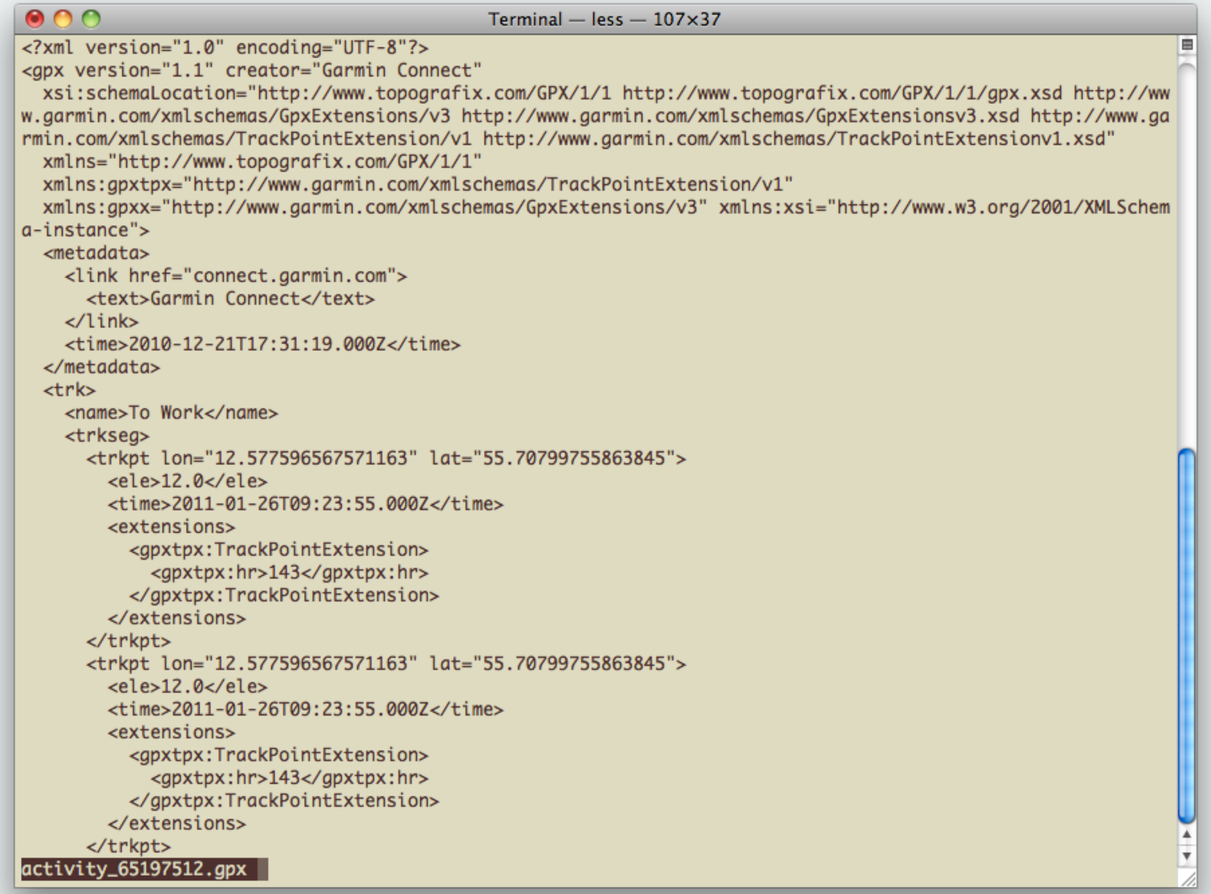
1
1000

1
1000

.

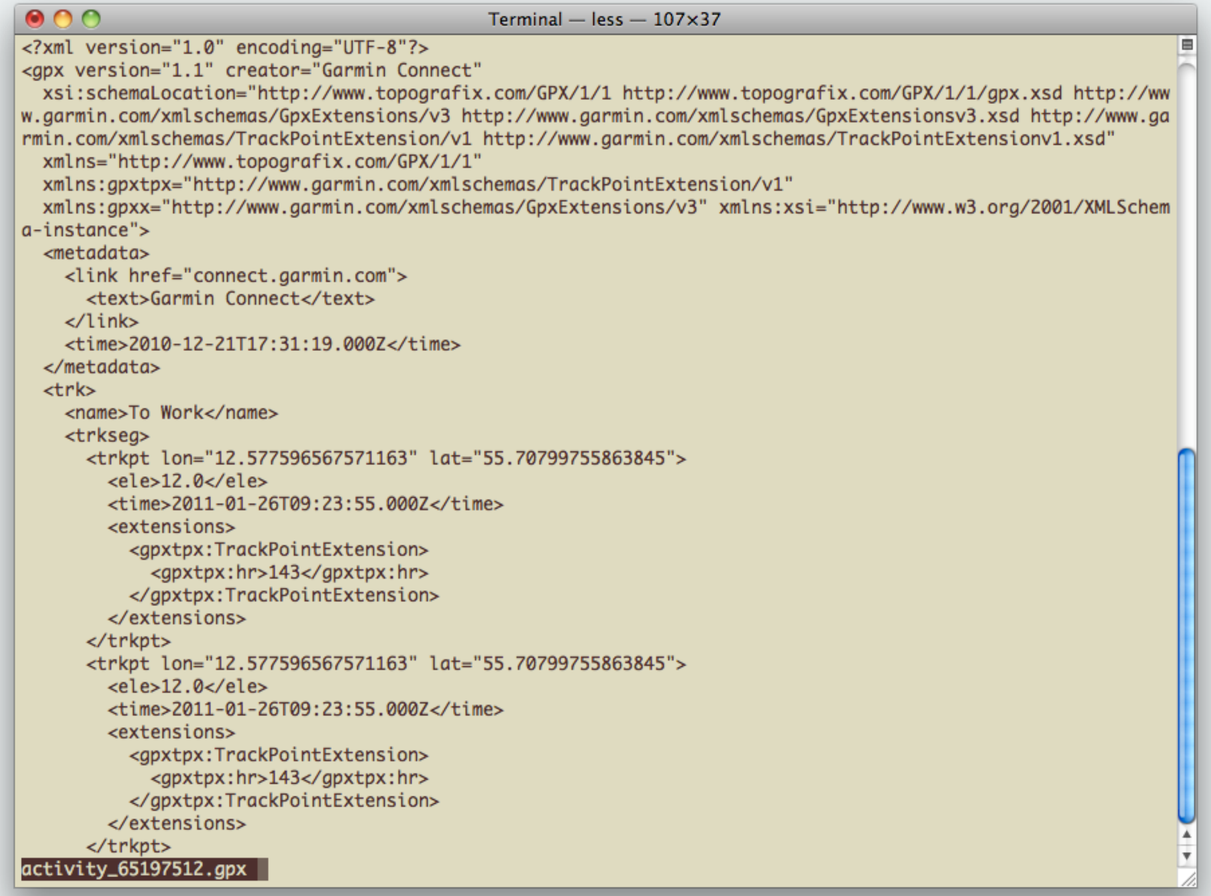
This is data

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



This is location 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:

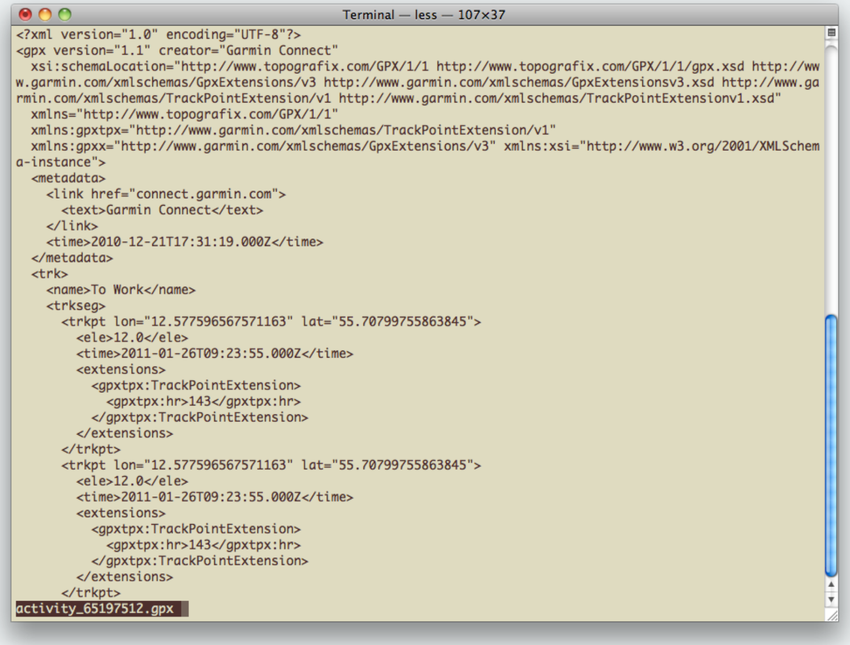
- Narrow spectrum of data that we can process and understand
- Limited memory for processing new information
- Limited attention for undertaking focussed tasks

The human eye is made for advanced pattern recognition

It can:

- Immediately recognize a pattern in a highly complex image
- Quickly spot things that deviate from patterns (outlier detection)
- Process streams of images and recognize patterns over time

Data must be rendered in human-friendly format



?

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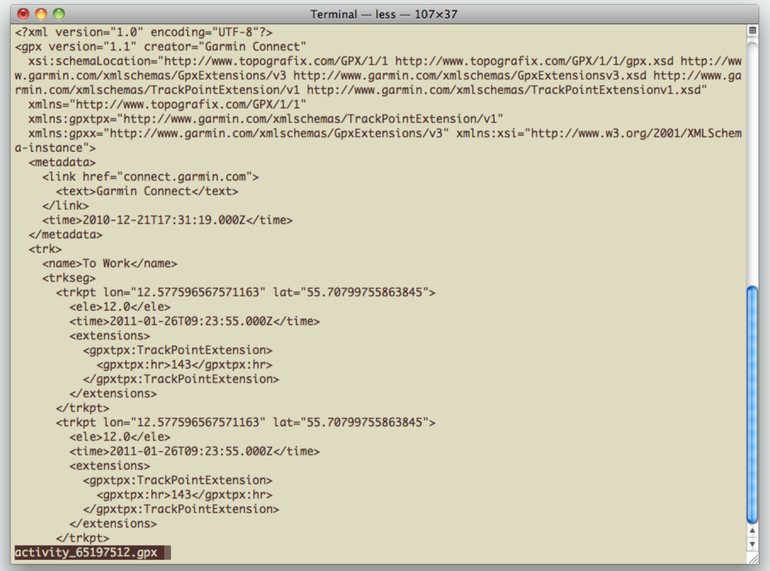

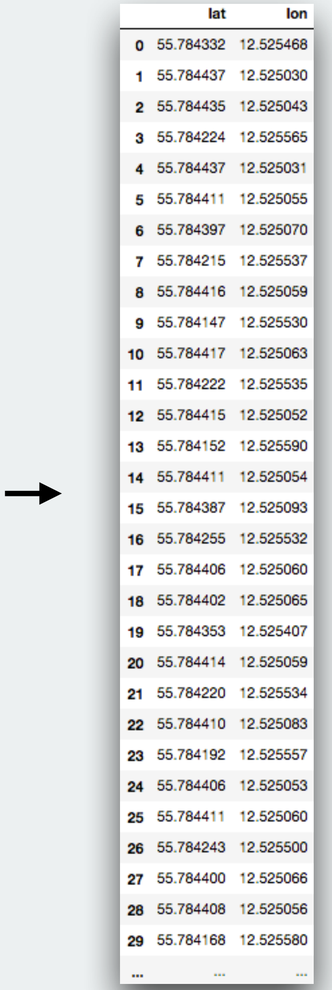

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1	55.784437	12.525030
2	55.784435	12.525043
3	55.784224	12.525565
4	55.784437	12.525031
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6	55.784397	12.525070
7	55.784215	12.525537
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21	55.784220	12.525534
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26	55.784243	12.525500
27	55.784400	12.525066
28	55.784408	12.525056
29	55.784168	12.525580
...	...	...

?

Data must be rendered in human-friendly format

Terminal — less — 107×37

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  <metadata>
    <link href="connect.garmin.com">
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  </metadata>
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activity_65197512.gpx
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→

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...	...	...

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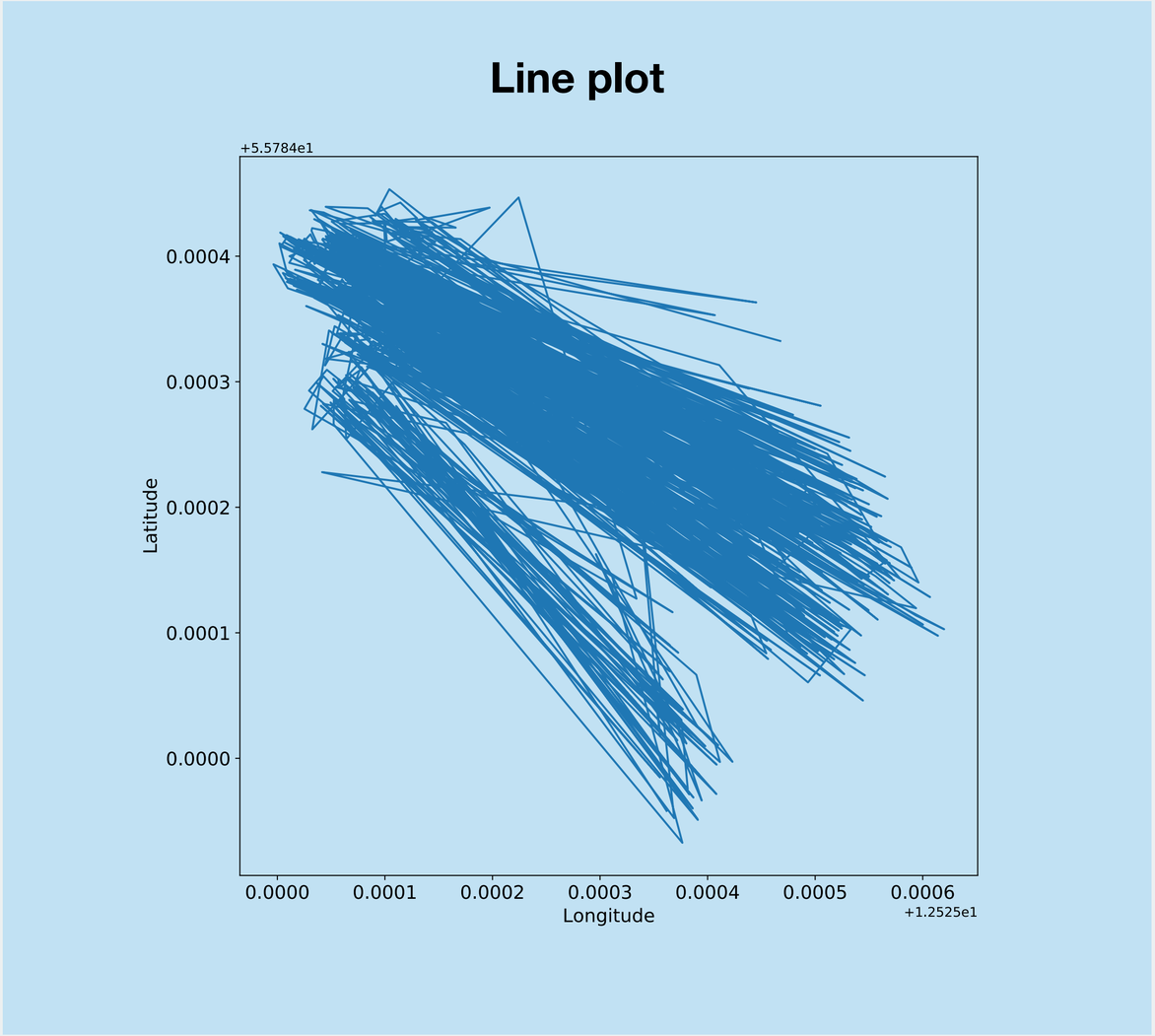

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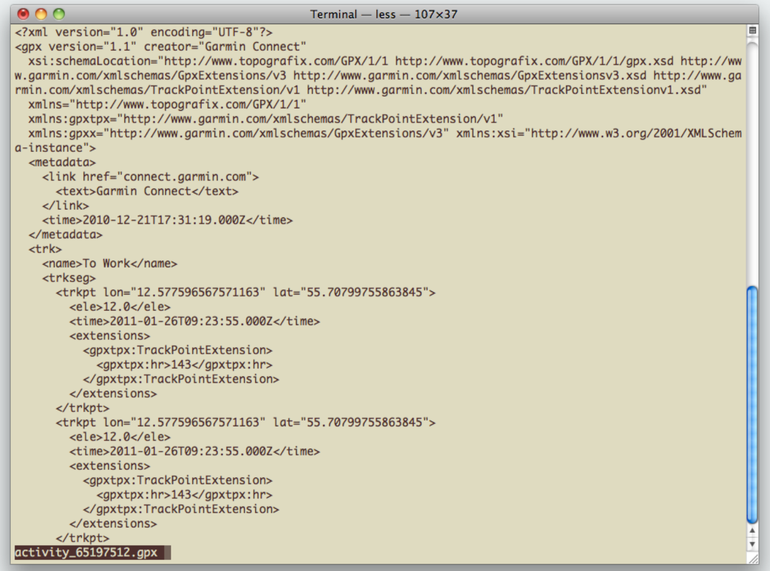

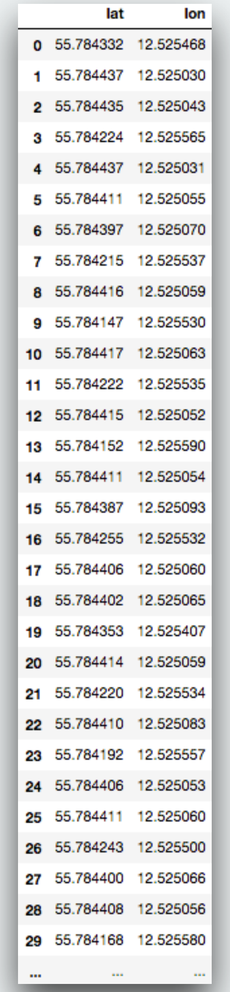

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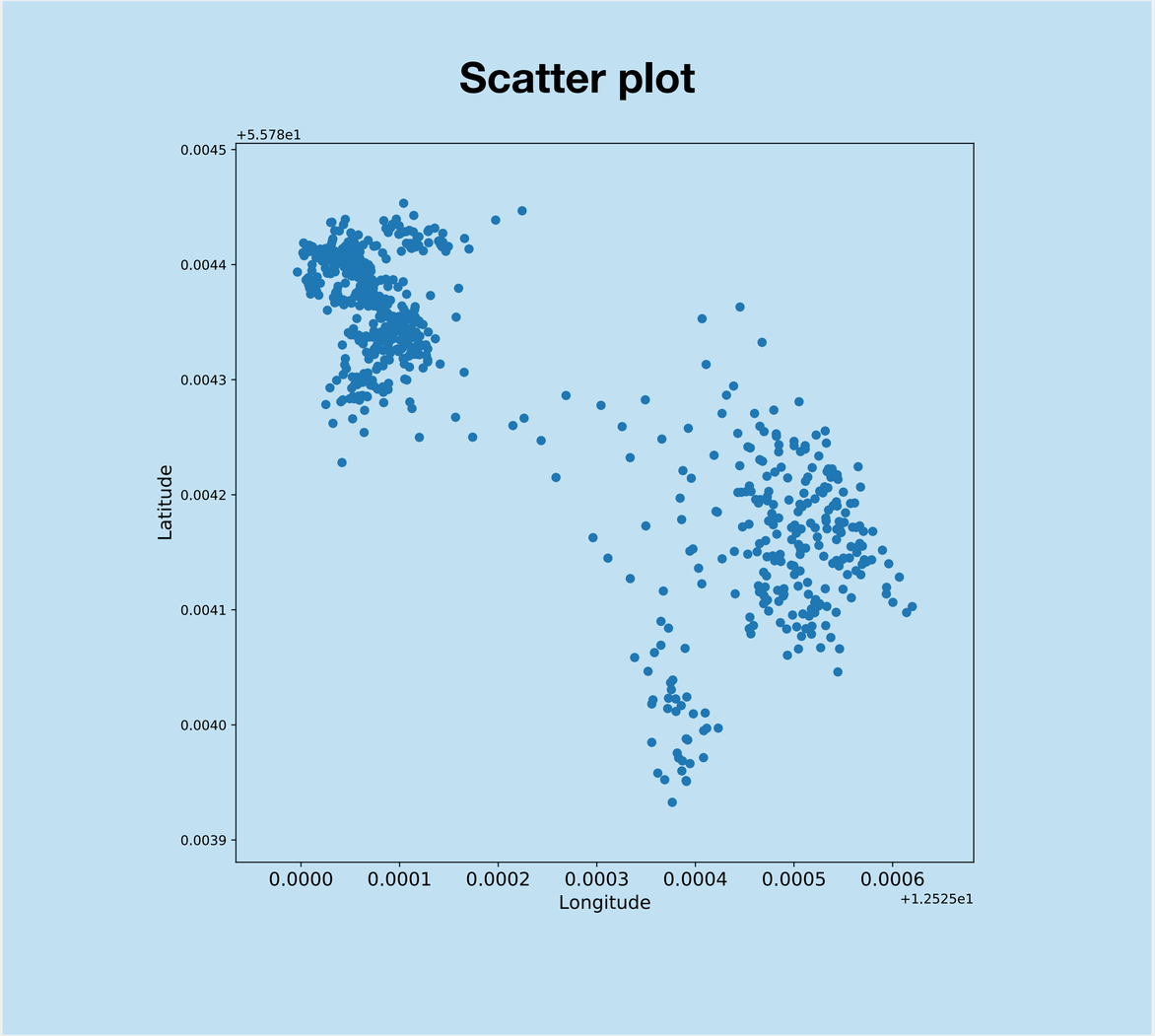

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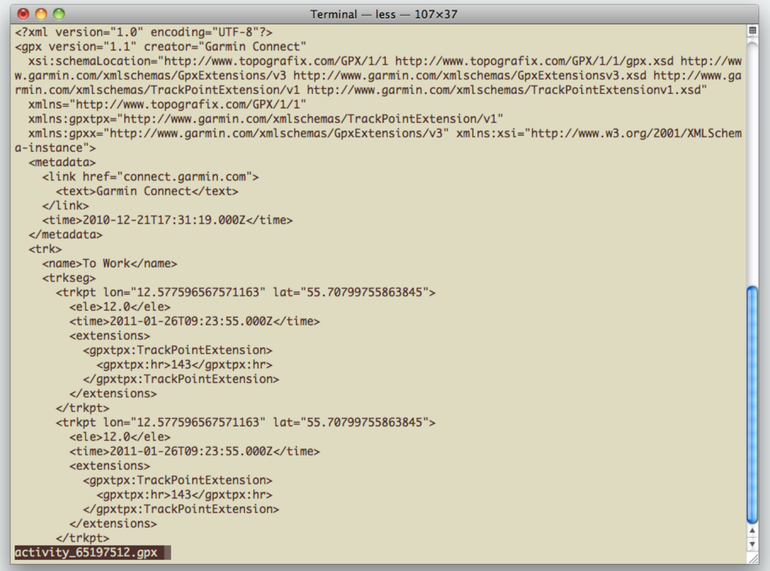

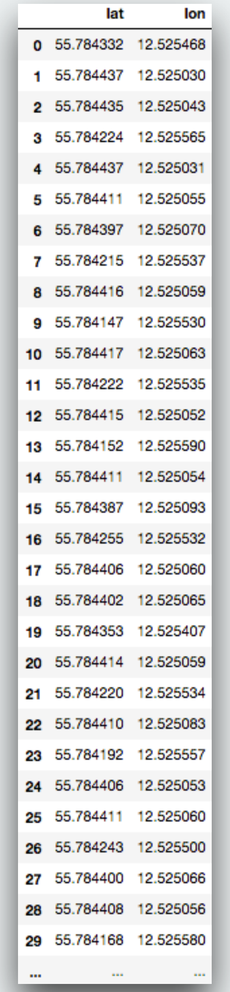

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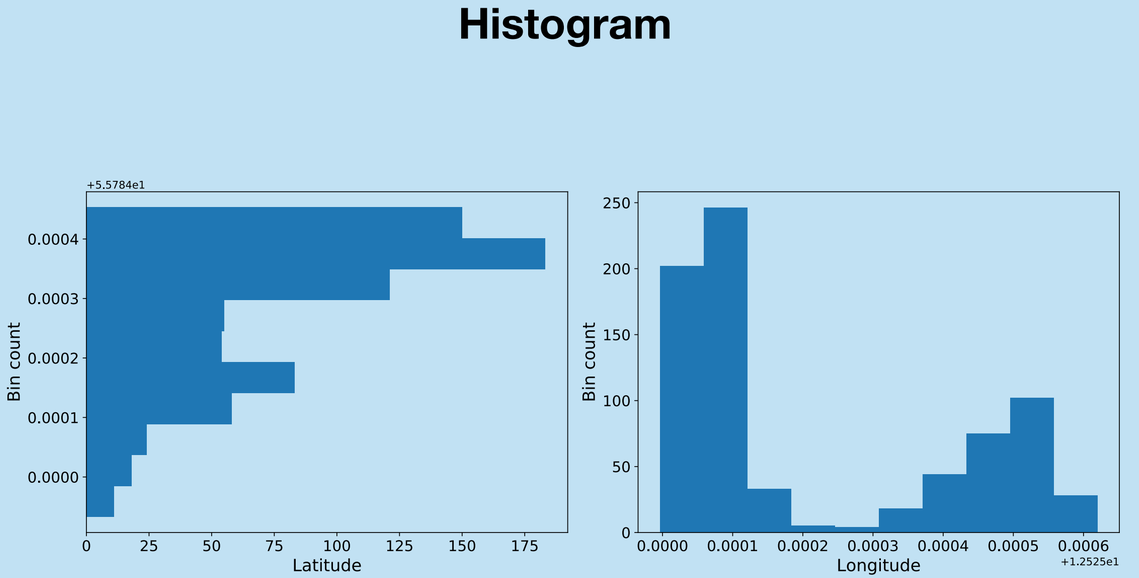

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  xmlns="http://www.topografix.com/GPX/1/1"
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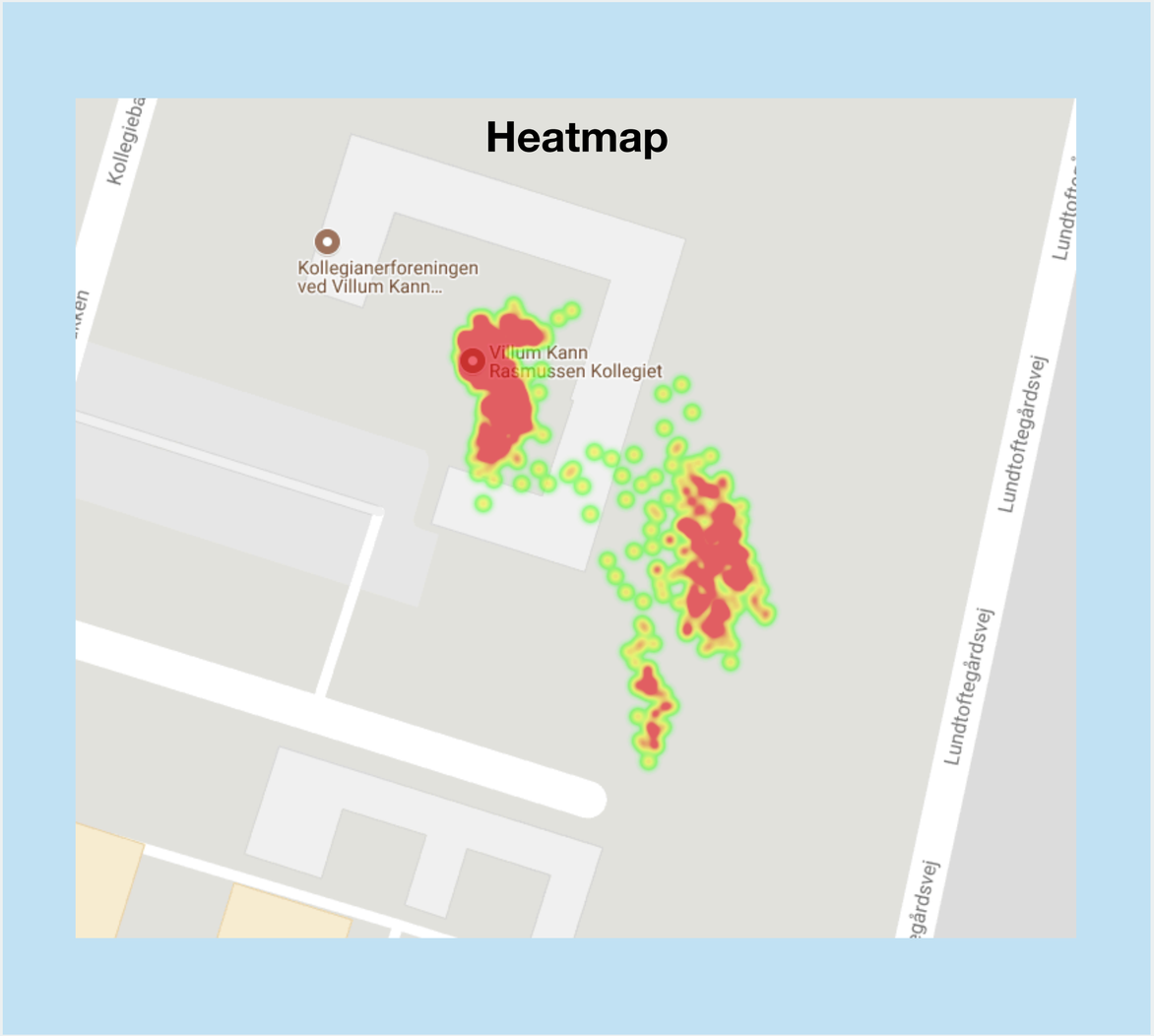
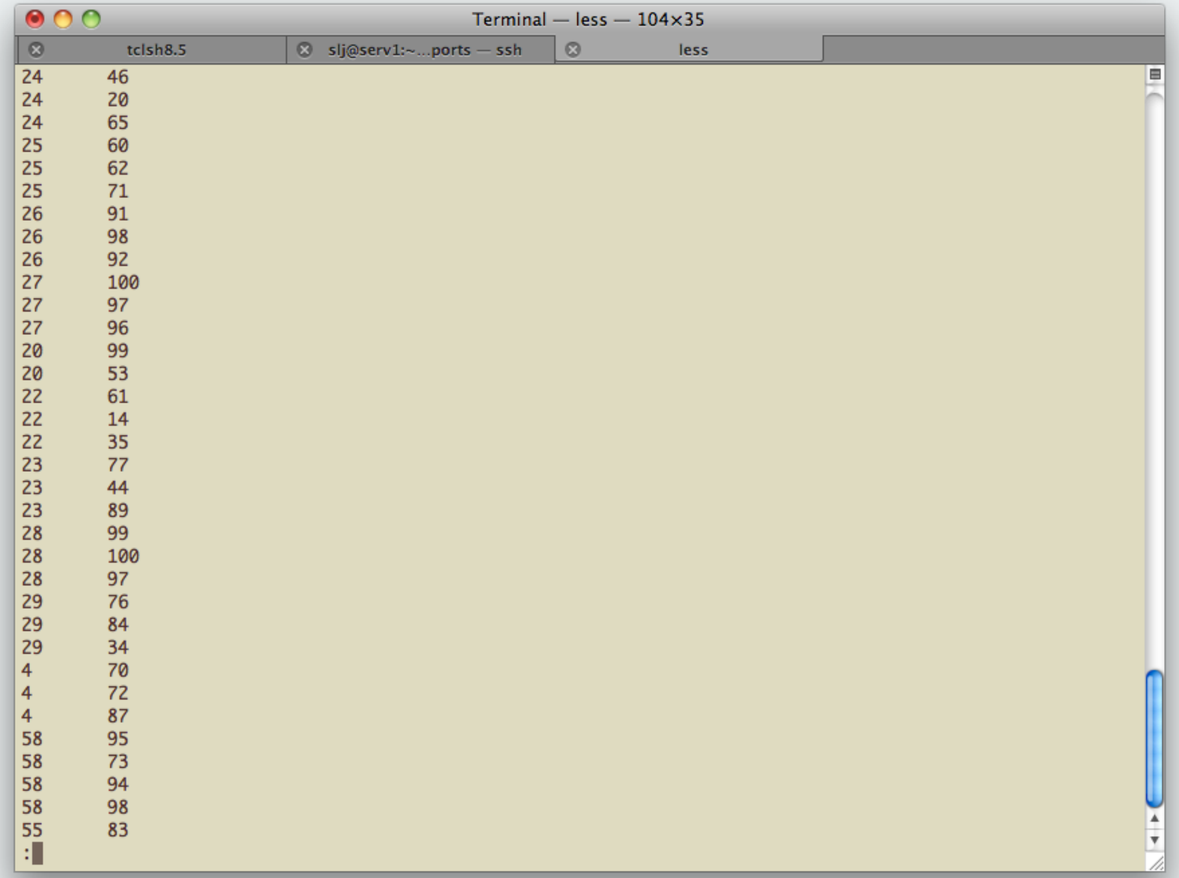
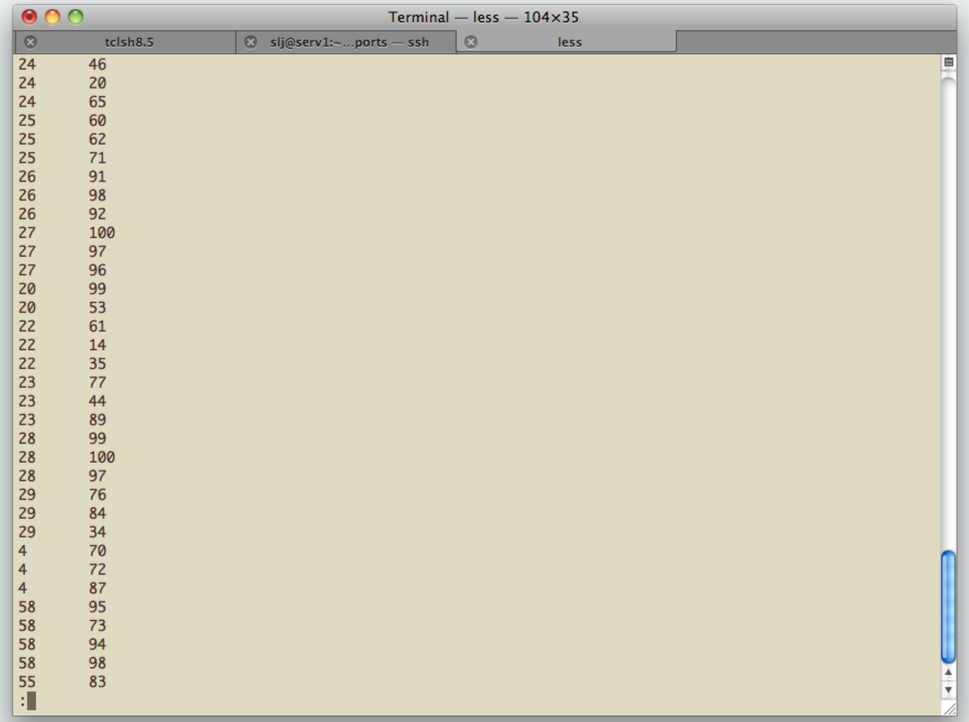
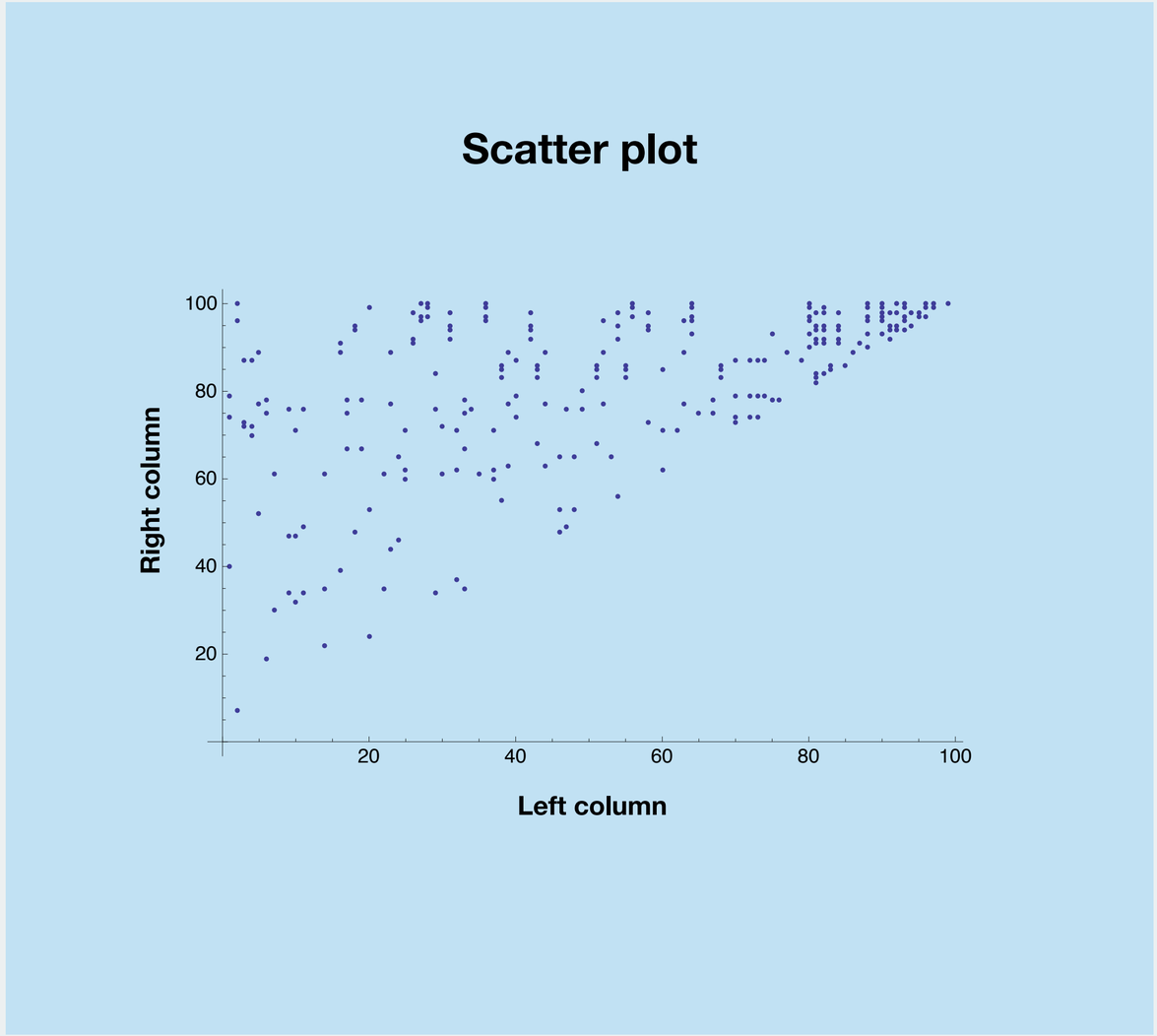


Relational data

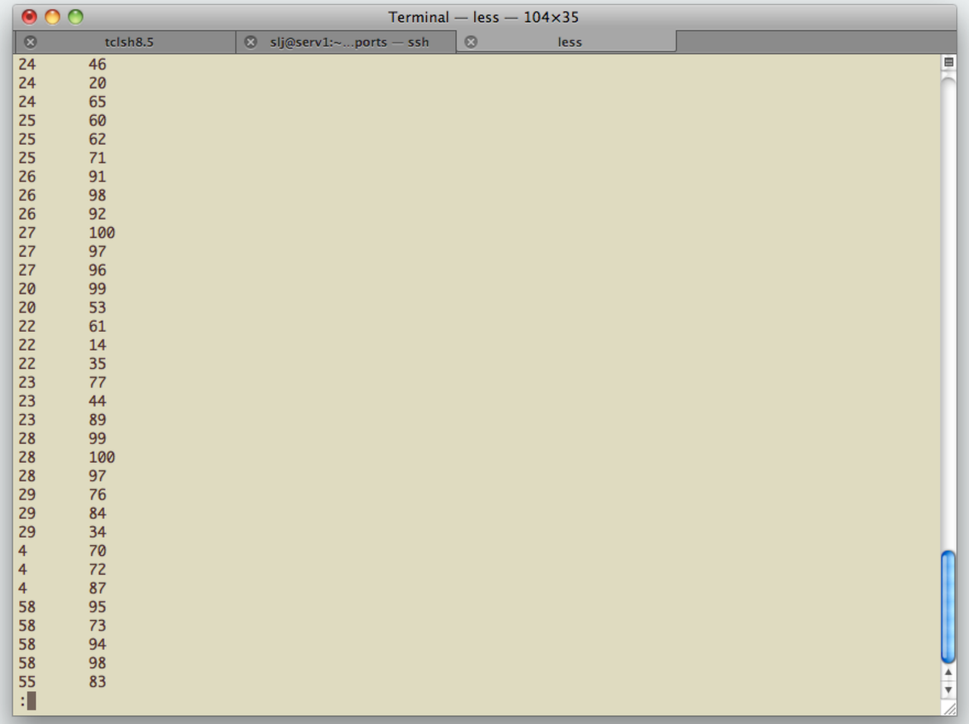


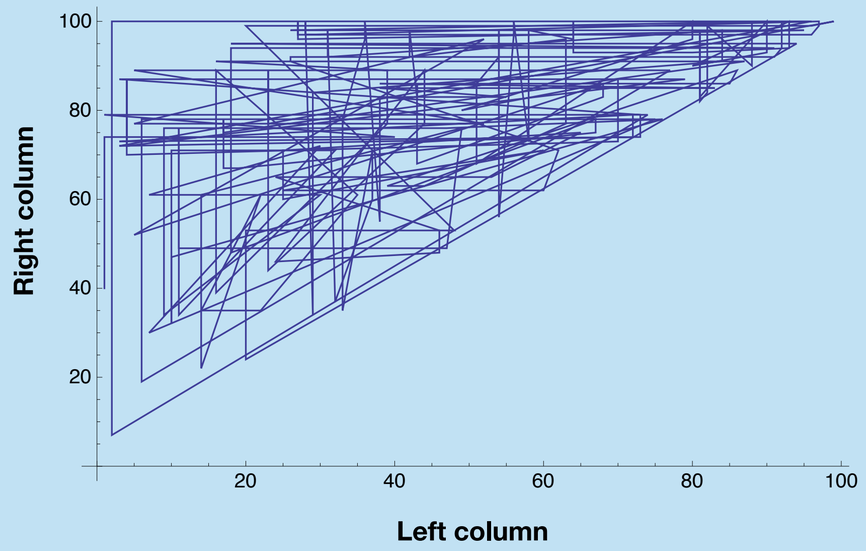
Relational data



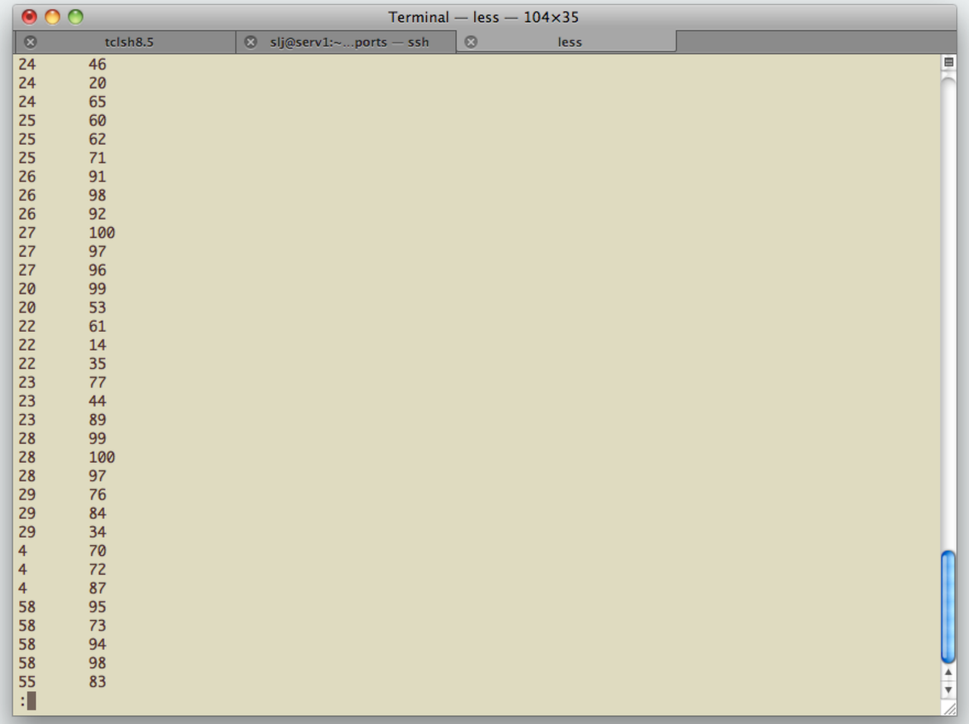


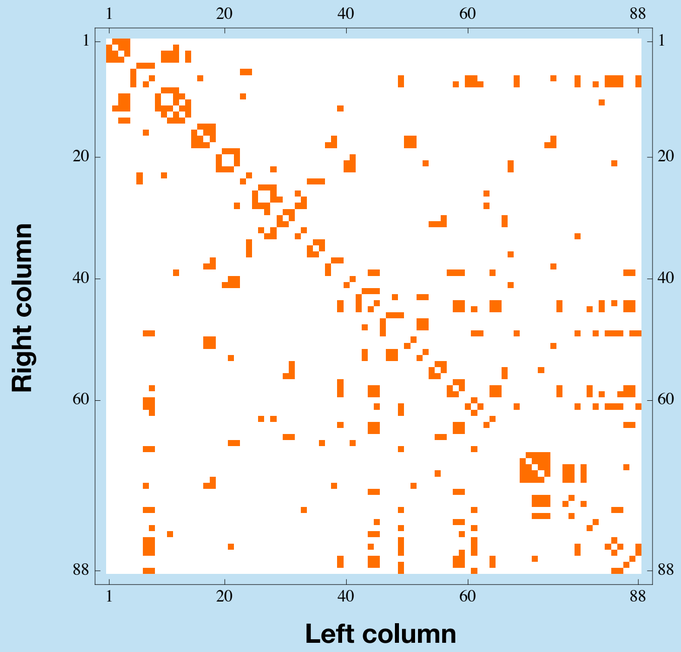
Relational data



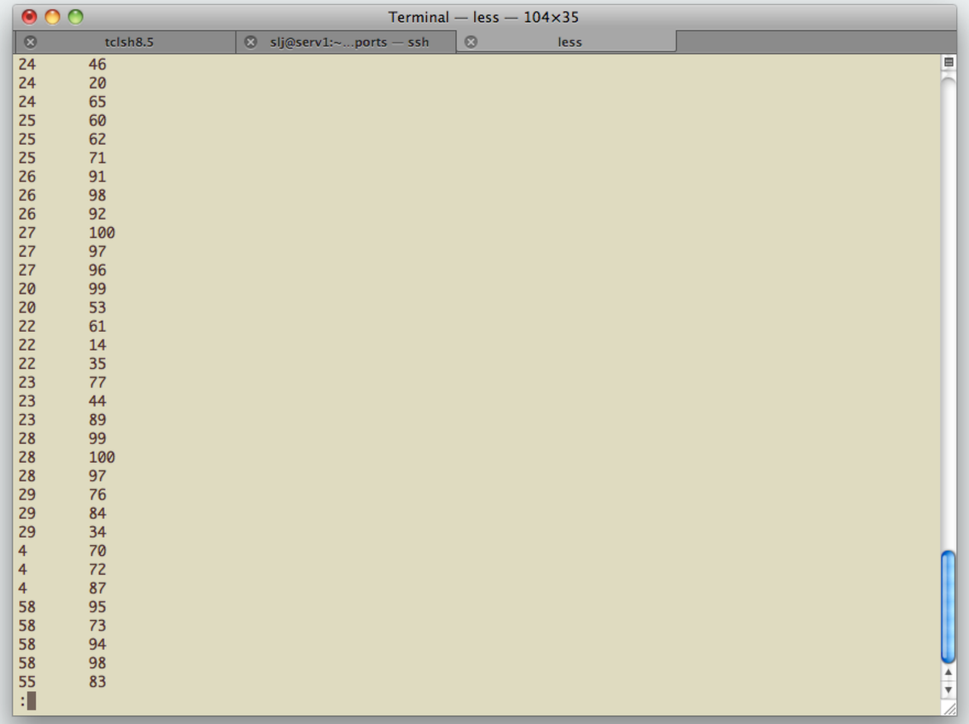


Relational data



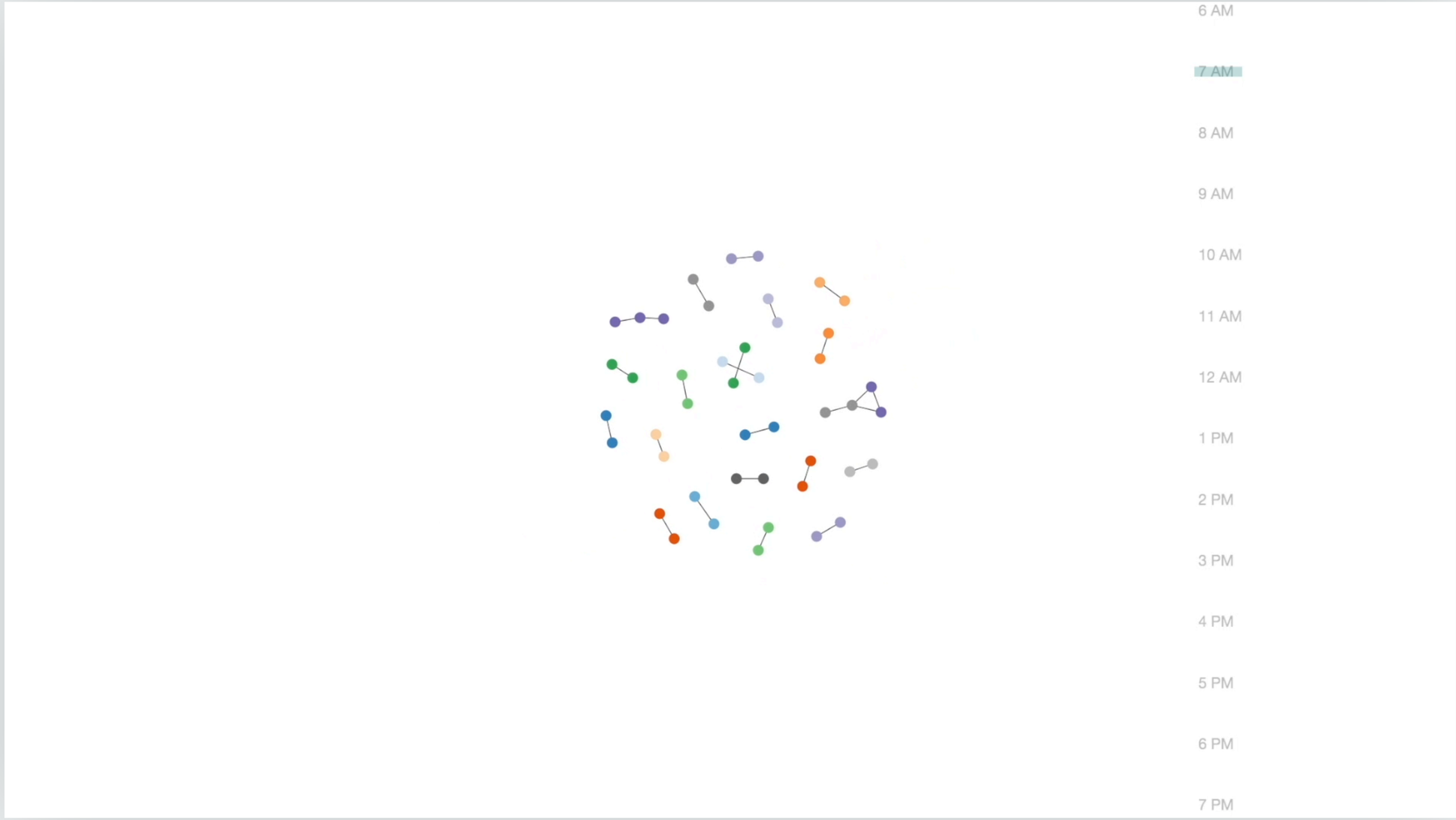


Relational data



Network

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

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For understanding how data is distributed

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For understanding how variables in data compare 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 compare and develop	• Scatter plots • Pairs plot • Time series plot • Line plot • Bar plot
For understanding interrelations in highly connected data	• Networks

Linear algebra

Linear algebra

A principled and scalable method for manipulating data

Linear algebra

A principled and scalable method for manipulating data

Objects

- Scalars
- Vectors
- Matrices

Everything is a Tensor!

Linear algebra

A principled and scalable method for manipulating data

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- Scalars
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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

A principled and scalable method for manipulating data

Objects

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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
```

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

A principled and scalable method for manipulating data

Objects

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Everything is a Tensor!

matrix

2D

```
In [4]: print np.random.randint(1, 100, size=(3, 3))
Last executed 2018-01-25 11:54:38 in 4ms
[[99 47 77]
 [15 82  9]
 [59 55 48]]
```

scalar

0D

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

vector

1D

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In [3]: print np.random.randint(1, 100, size=3)
Last executed 2018-01-25 11:53:37 in 5ms
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Linear algebra **A principled and scalable method for manipulating data**

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scalar

0D

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In [2]: print np.random.randint(1, 100)
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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]
```

matrix

2D

```
In [4]: print np.random.randint(1, 100, size=(3, 3))
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]]

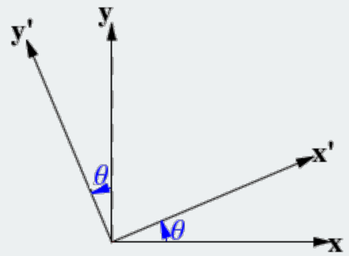
 [[86 58 61]
  [71 95 86]
  [92 19 68]]]
```

Linear algebra **A principled and scalable method for manipulating 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

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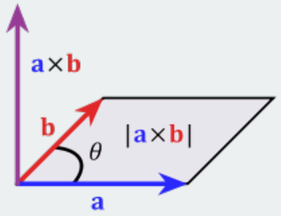

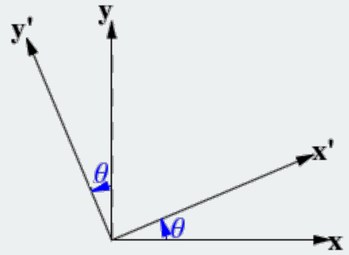

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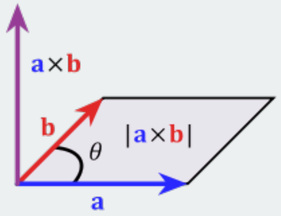

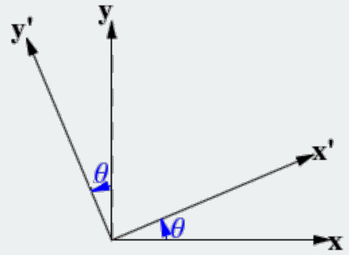

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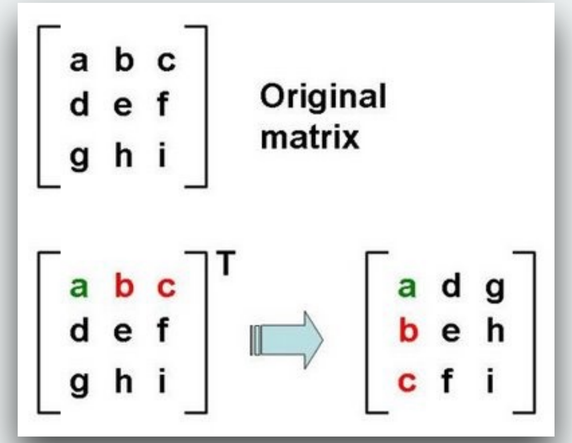

Statistics

Statistics

A set of tools and jargon for describing data

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Vocabulary

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

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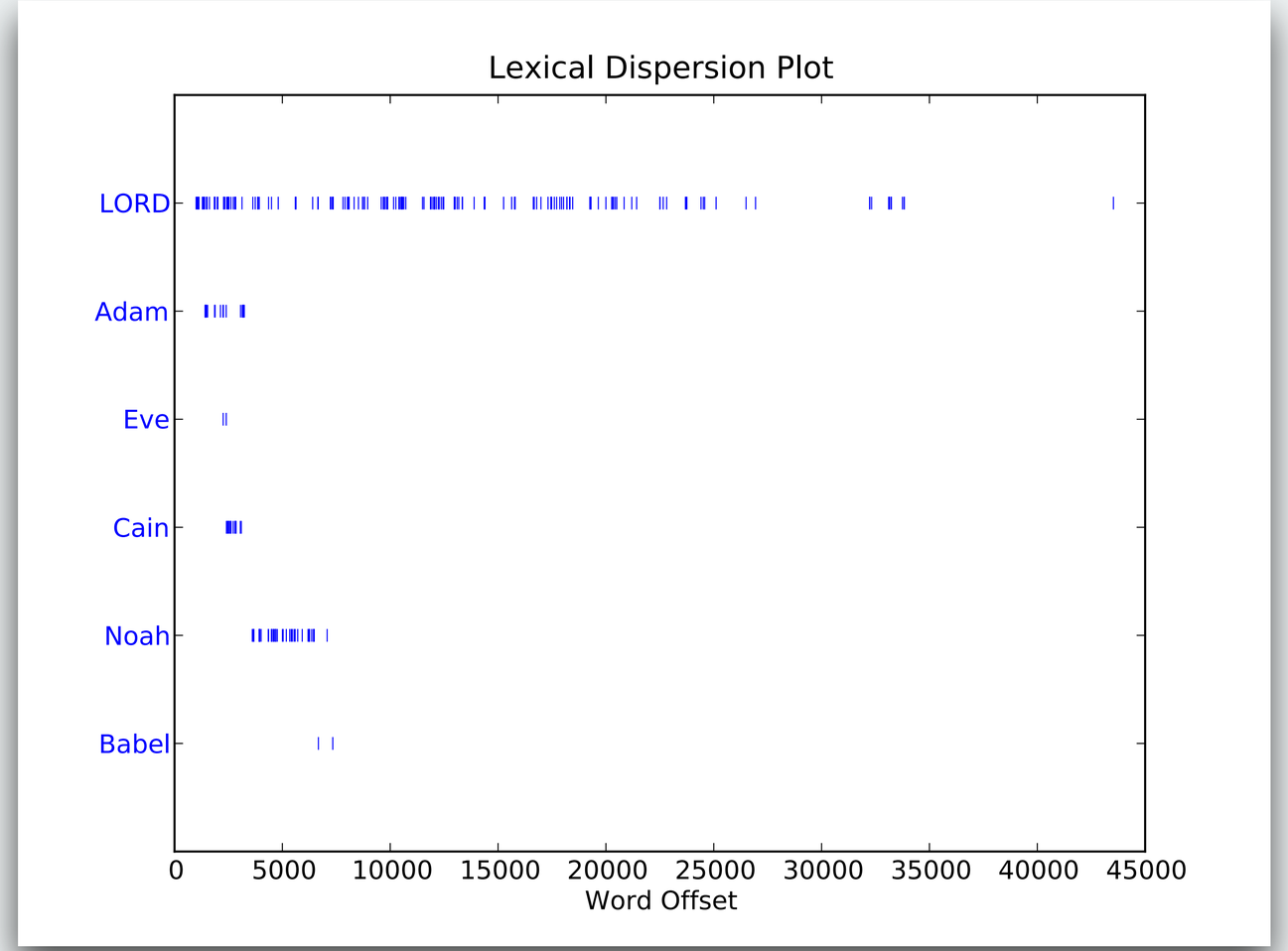

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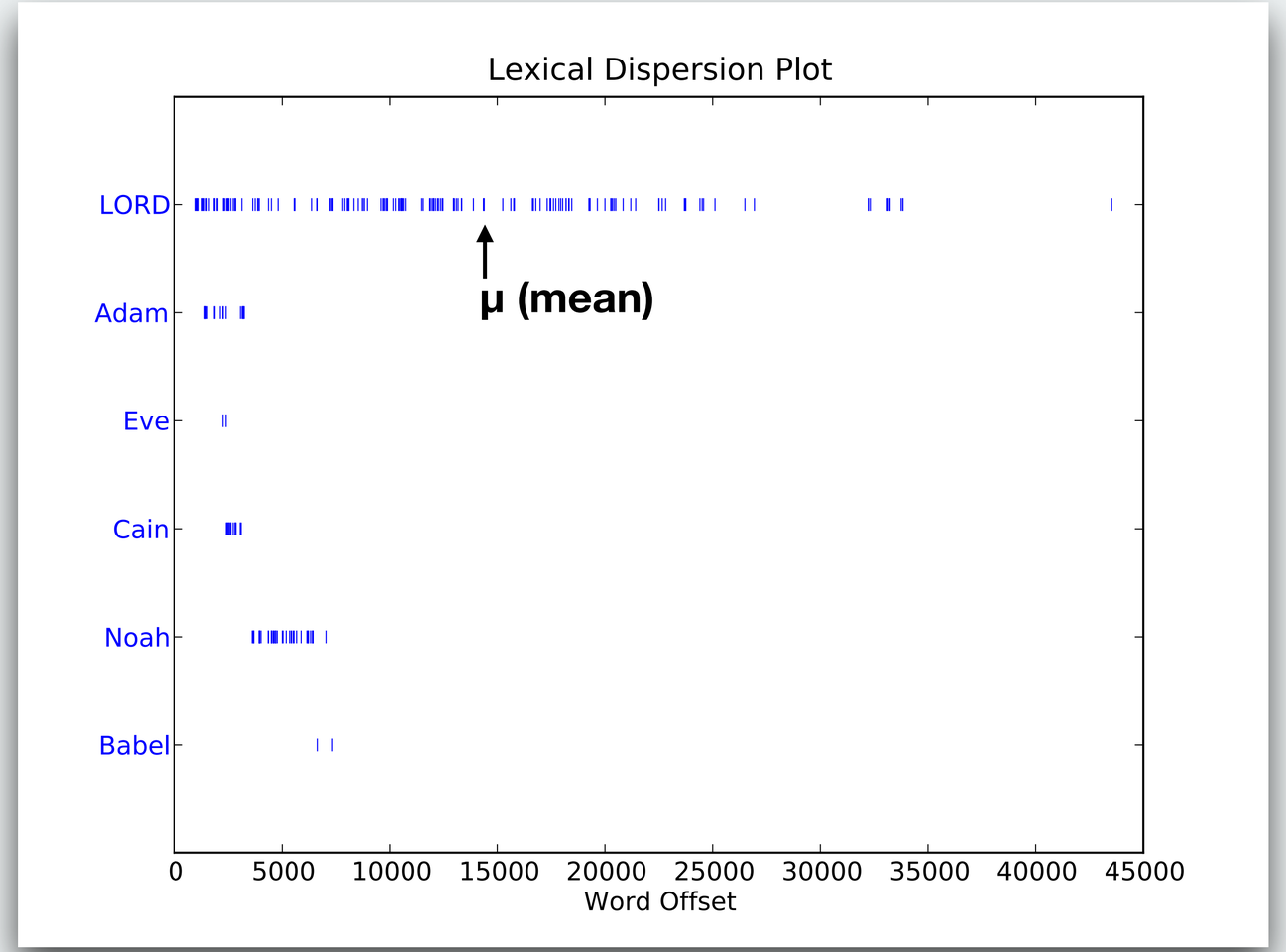
$$\mu = \frac{\text{Sum of values}}{\text{Number of values}}$$



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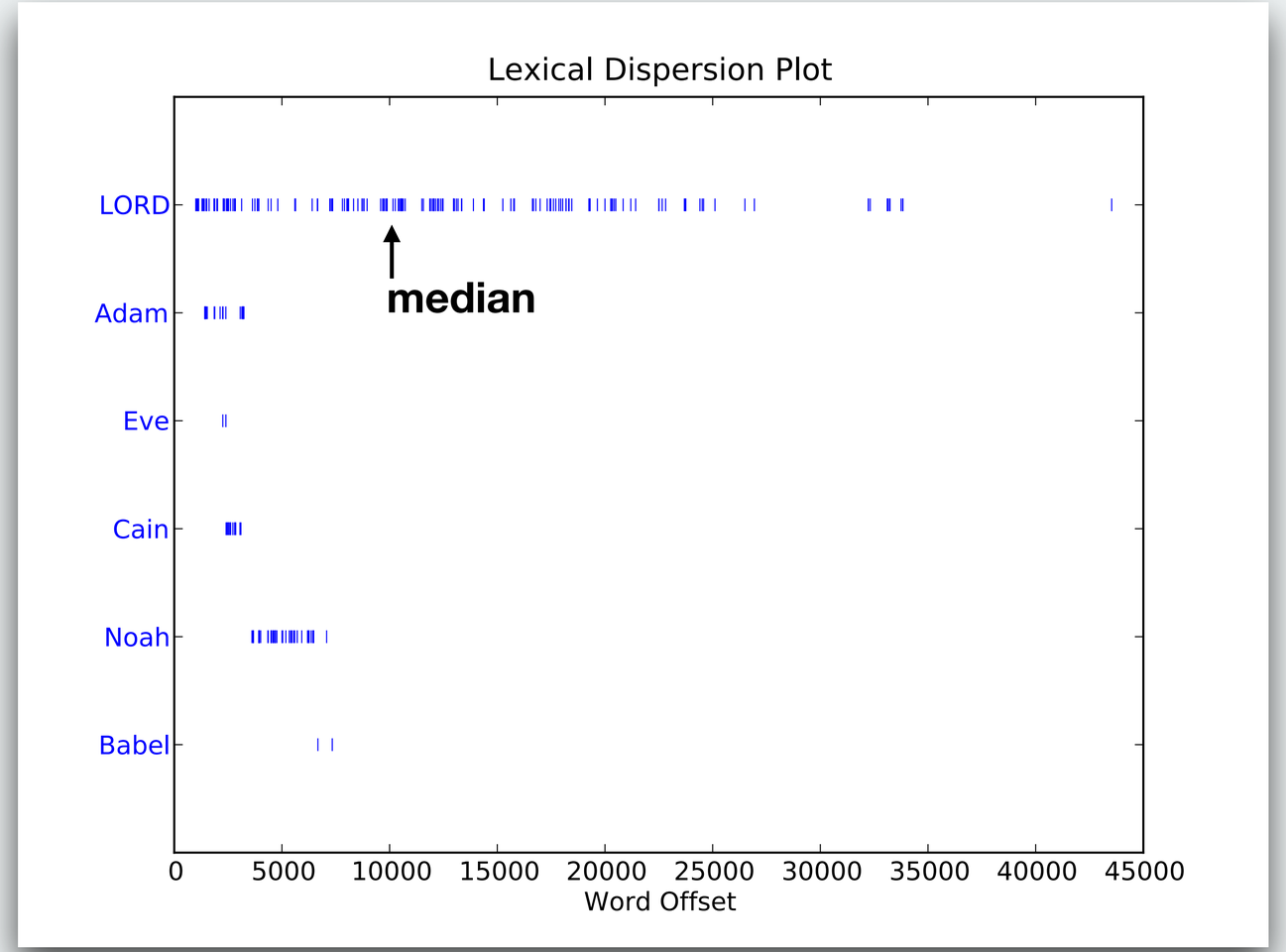
median = Middle number in ordered list



Statistics

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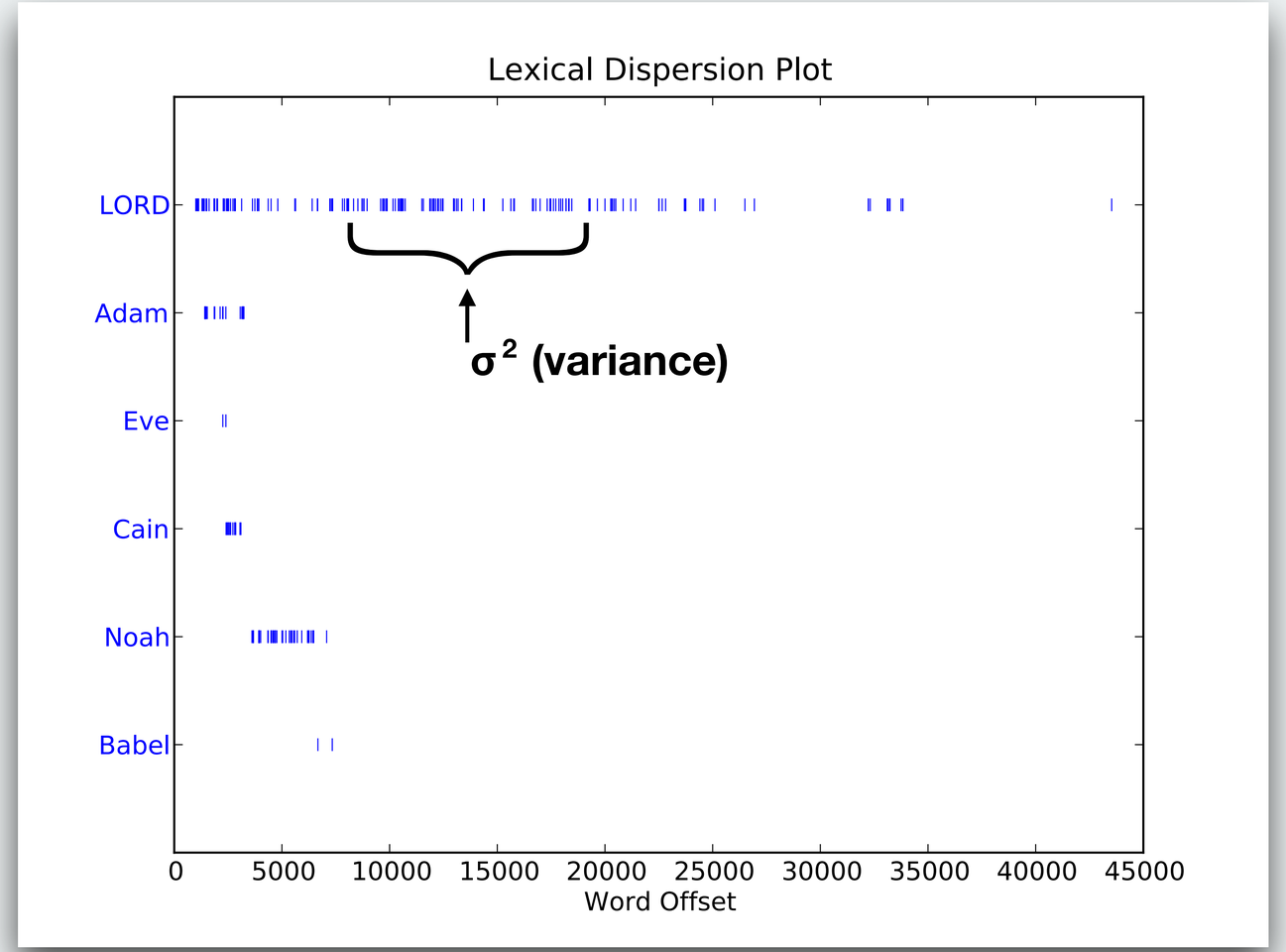
$$\sigma^2 = \frac{1}{N-1}\sum_{i=1}^{n}(x_i - \mu)^2$$



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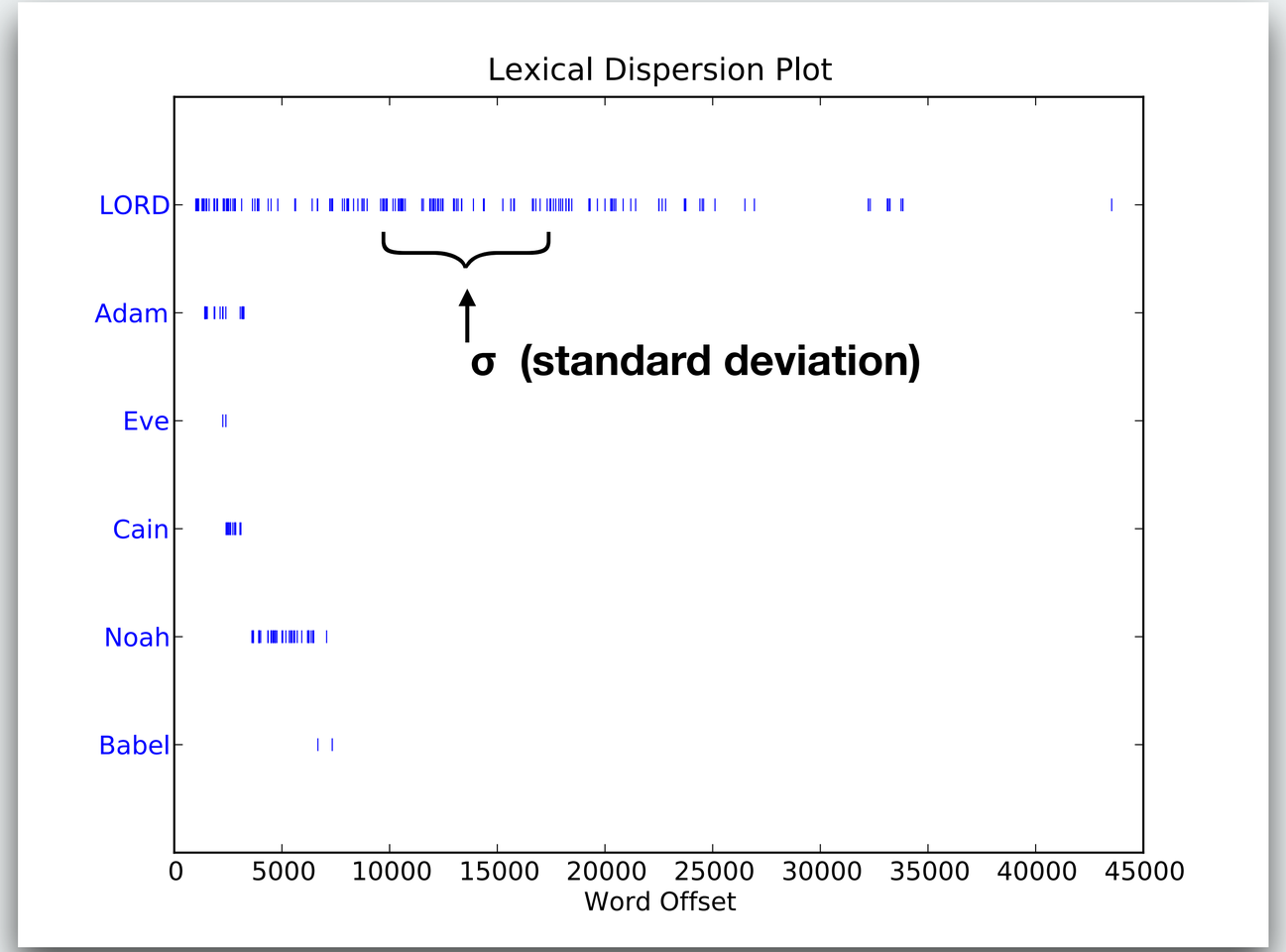
$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{n}(x_i - \mu)^2}$$



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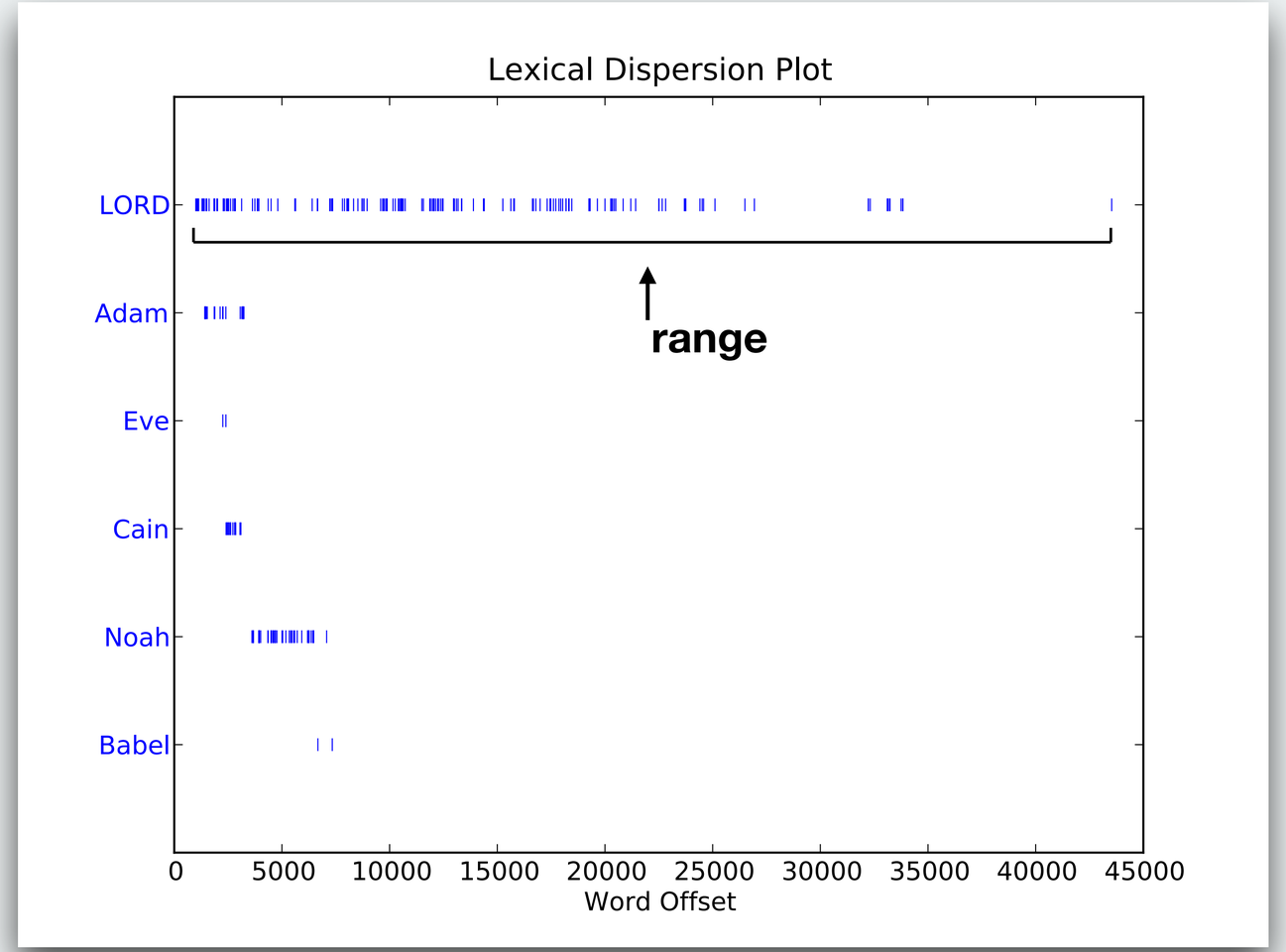
range = max(value) - min(value)



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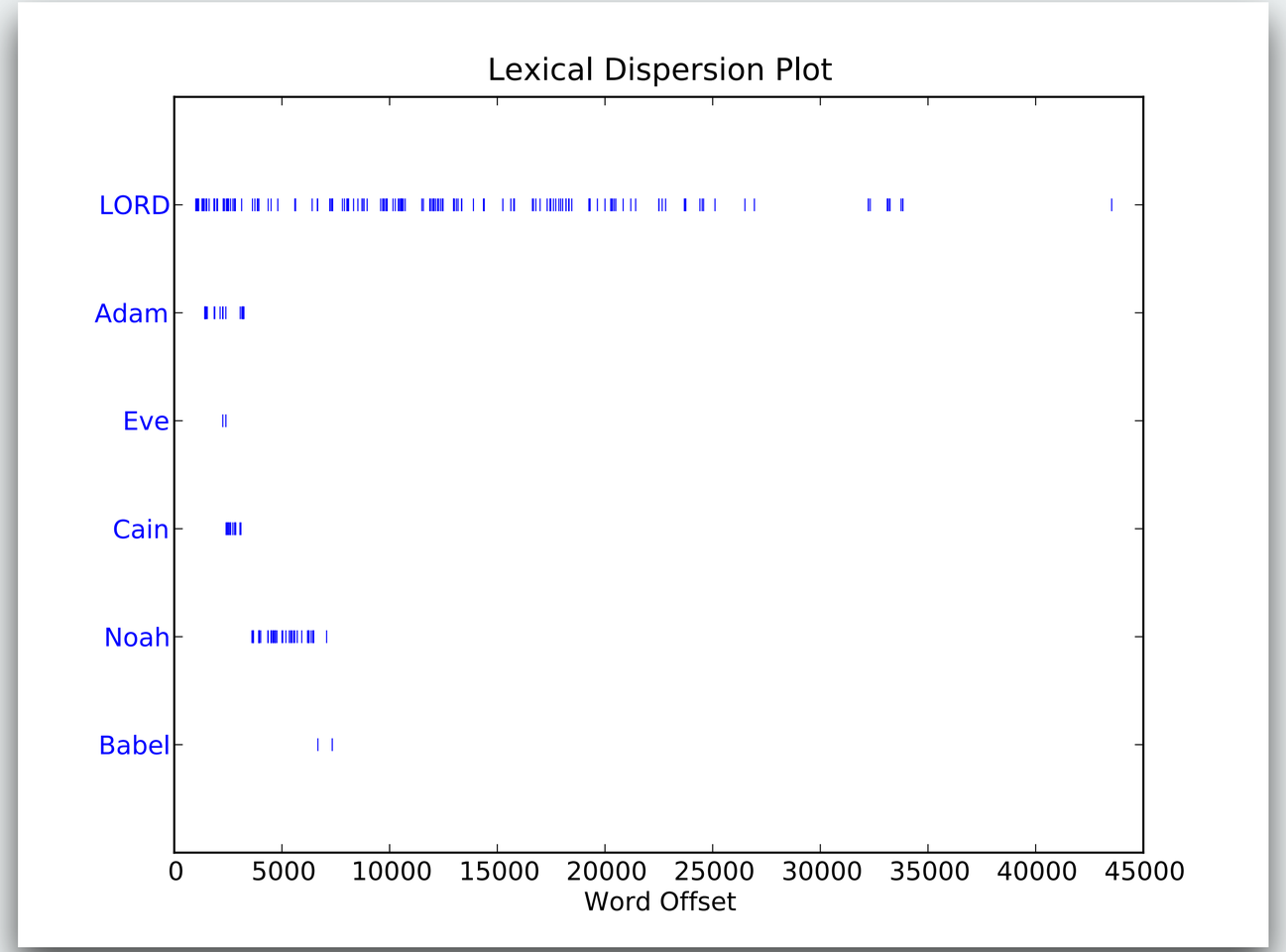
cov(X, Y) = $\frac{1}{n}\sum_{i=1}^{n}(x_i - \mu_X)(y_i - \mu_y)$



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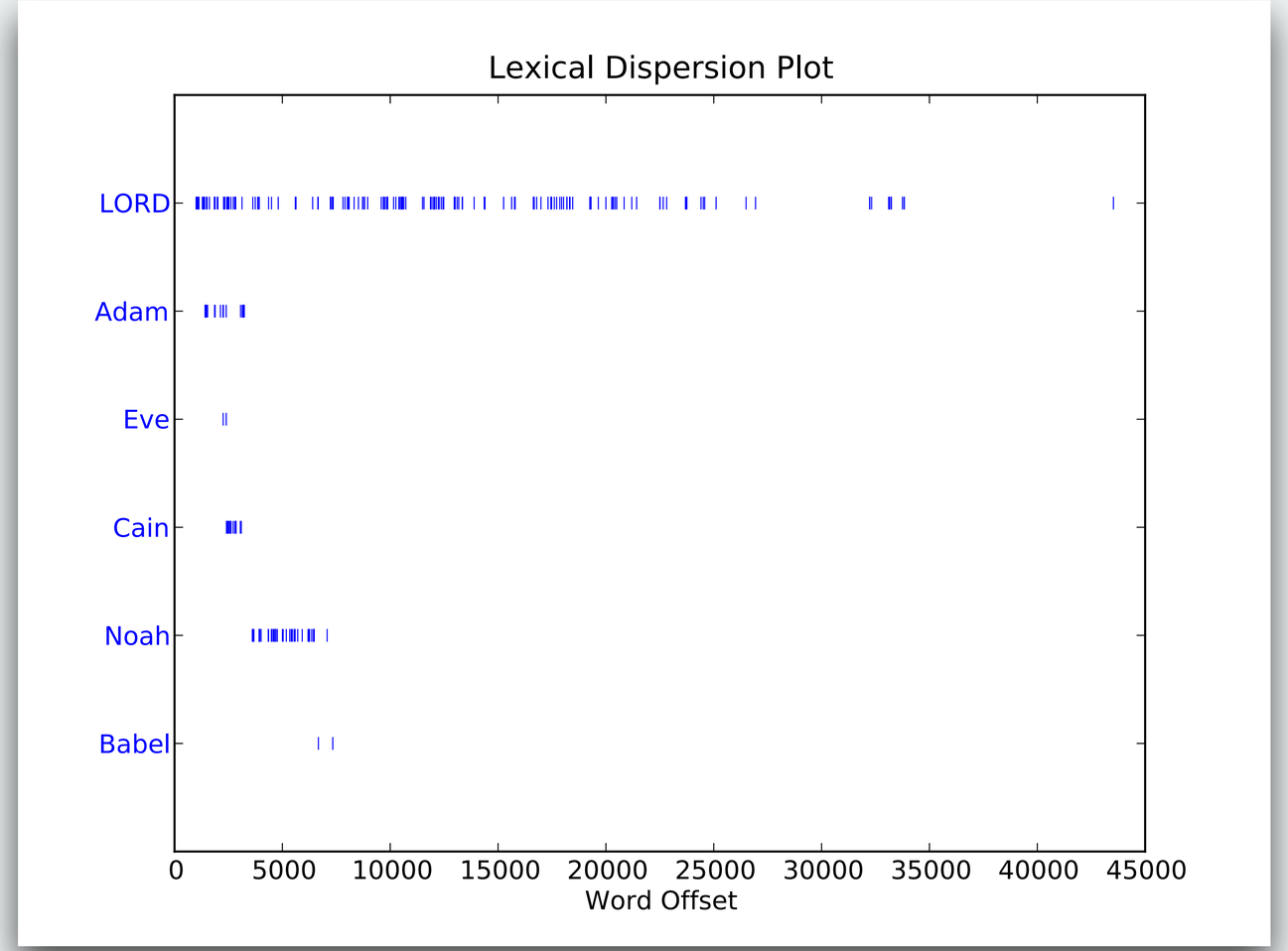
$$\textbf{cor(X, Y)} = \frac{cov(X, Y)}{\sigma_X \sigma_Y}$$



Probability theory

Probability theory

Formalized framework for dealing with randomness

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Formalized framework for dealing with randomness

Important concepts

- Discrete vs. continuous
- Distribution and process
- Random and stochastic
- Probability functions
  - Probability *mass* function (pmf)
  - Probability *density* function (pdf)
  - *Cumulative density* function (cdf)

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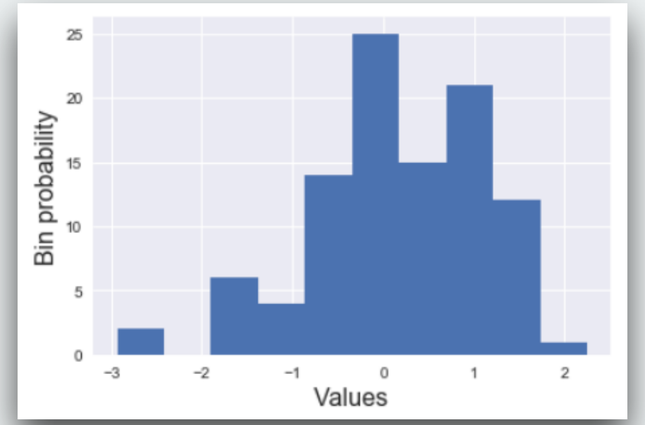
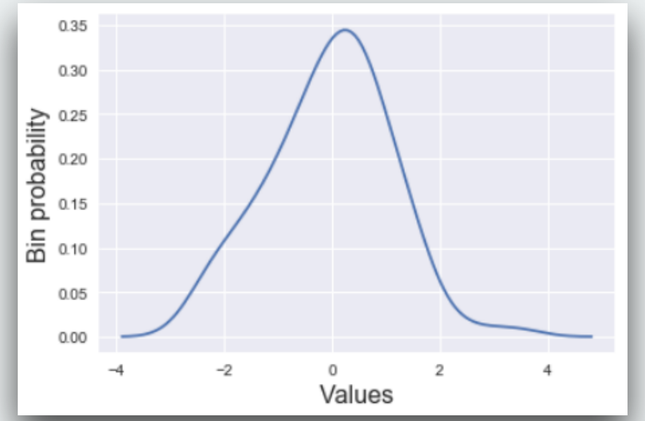
Discrete



Continuous



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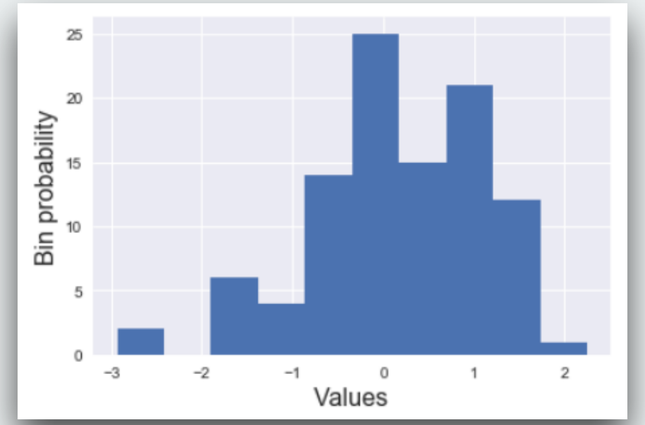
Distribution



Process

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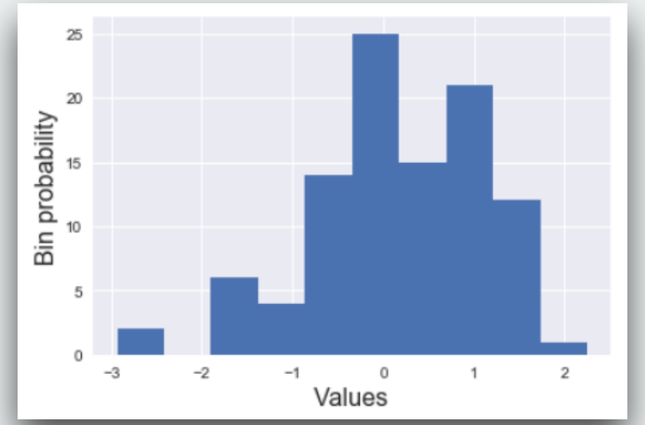
A **variable** is *random*



A **process** is *stochastic*

Otherwise the two words mean the same

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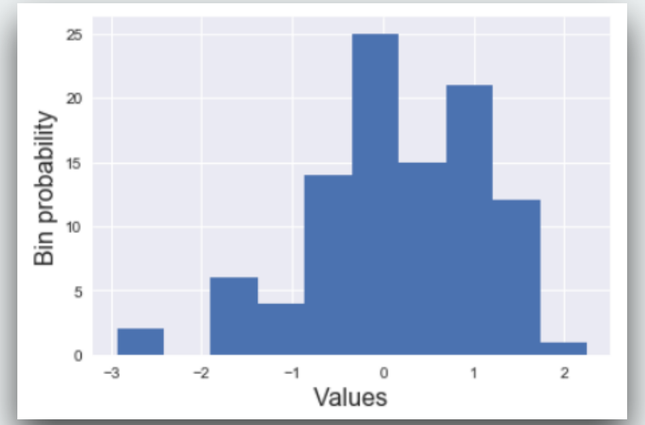
pmf



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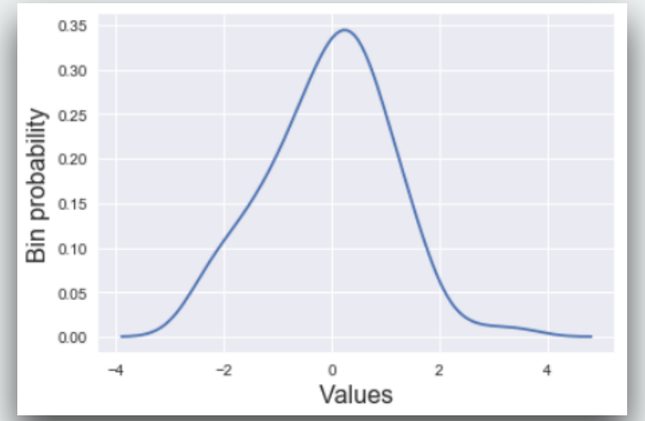
pdf



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cdf