What Is Exploratory Data Analysis?

> *But as much as EDA is a set of tools, it's also a mindset. And that mindset is about your relationship with the data… EDA happens between you and the data and isn't about proving anything to anyone else yet.*

- Cathy O'Neil (Doing Data Science)

What Is Exploratory Data Analysis?

- Developed at Bell Labs in the 1960's by John Tukey
- Techniques used to visualize and summarize data
  - Five-number summary: `describe()`
  - Distributions: box plots, stem and leaf, histogram, scatterplot

Goals of Exploratory Data Analysis

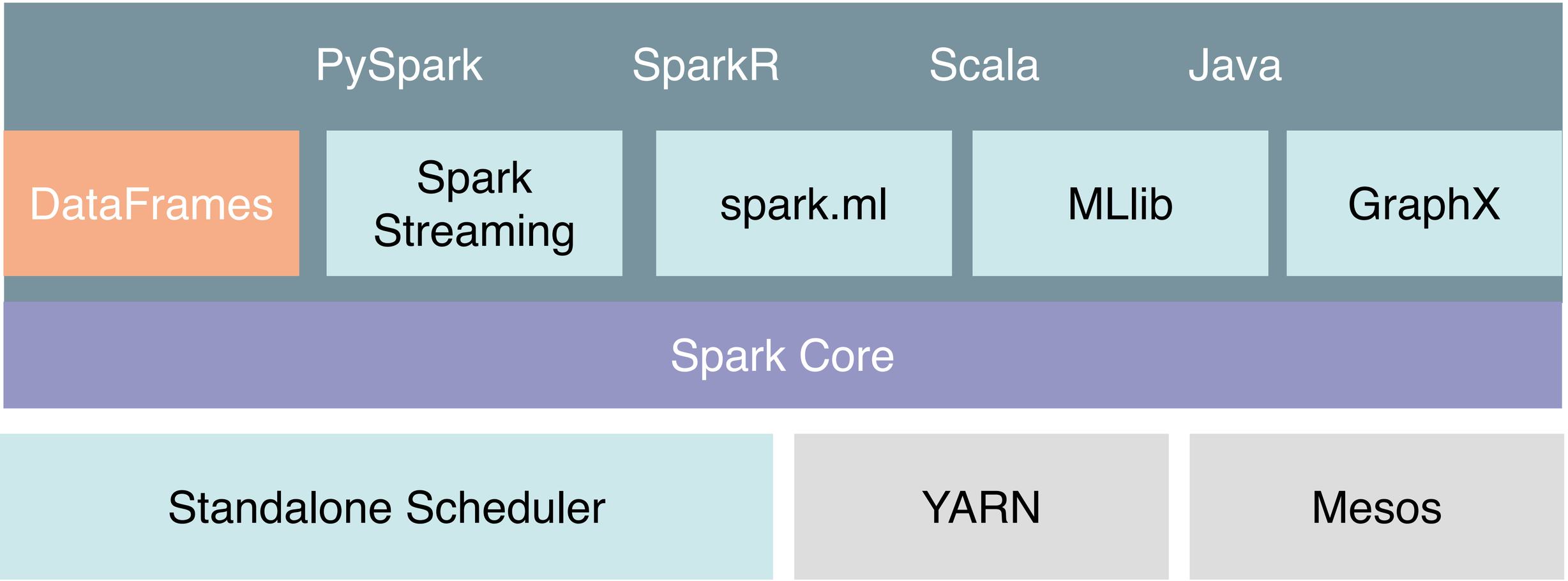
- Gain greater intuition
- Validate our data (consistency and completeness)
- Make comparisons between distributions
- Find outliers
- Treat missing data
- Summarize data (a statistic -> one number that represents many #'s)

How Can Spark Help?

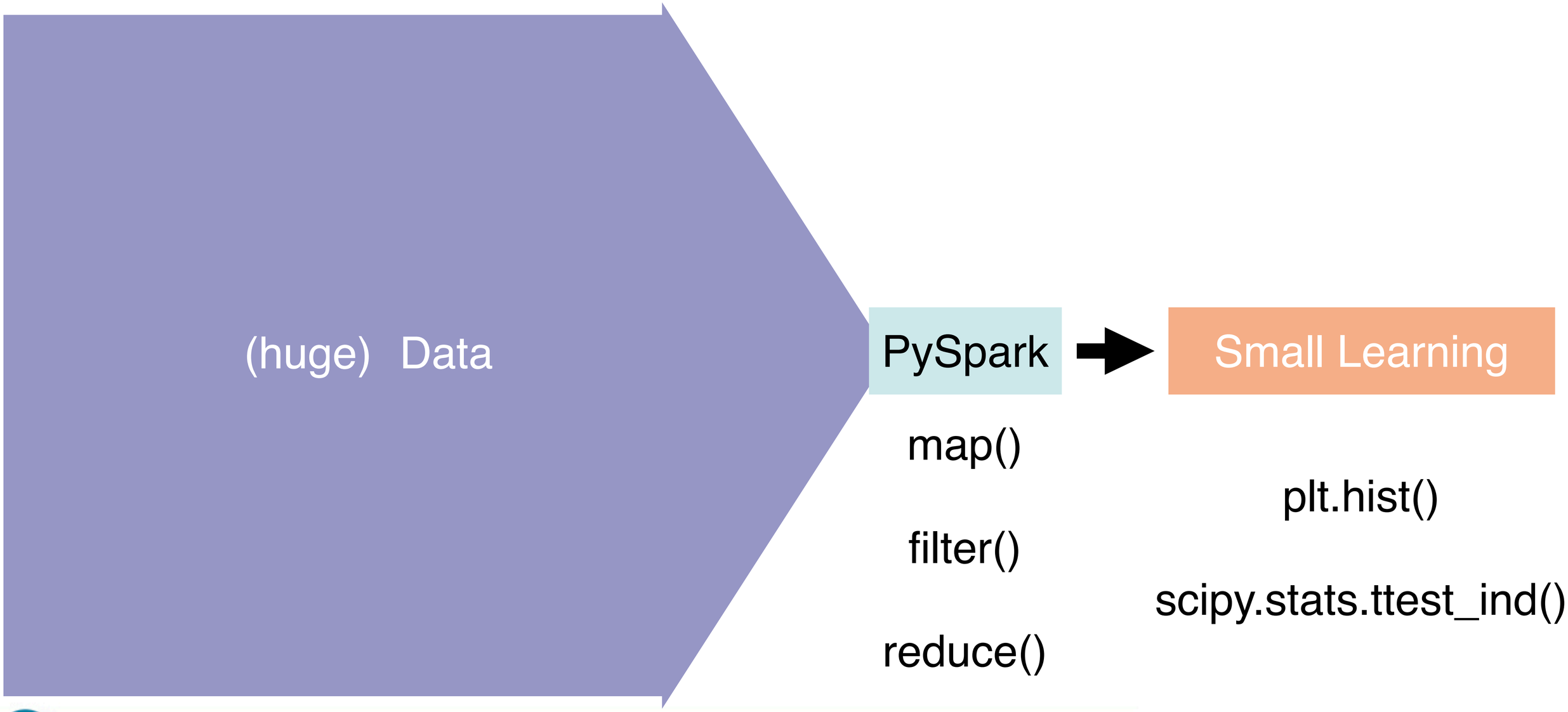
- Interactive REPL
- Rapid computation (especially aggregates) on large amounts of data
- High level abstractions for querying data
- “Condense” data for easier local exploration and visualization

Common Questions

- How many records in total are there?
- How many uniques values does each column contain?
- How many missing (or null) values are there?
- For numeric columns, what are its summary statistics
- What are values appear most often in each column?
- How are the values of each column distributed?


PySpark
SparkR
Scala
Java
DataFrames
Spark Streaming
spark.ml
MLlib
GraphX
Spark Core
Standalone Scheduler
YARN
Mesos

Big Data… Small Learning



Unique Values

- `rdd.distinct()`
- `rdd.countApproxDistinct(relative_accuracy)`

```
# HyperLogLog
rdd_dict.map(lambda row: row['_schoolid']).countApproxDistinct()
```

```
62989L
```

```
rdd_dict.map(lambda row: row['_schoolid']).distinct().count()
```

```
61402
```

http://dx.doi.org/10.1145/2452376.2452456

http://content.research.neustar.biz/blog/hll.html

Missing Values

- `column.isNull()`
- `dataframe.dropna(column_name)`
- `dataframe.fillna()`
- `dataframe.replace(to_replace, value)`
- `pyspark.accumulators`

https://spark.apache.org/docs/latest/api/python/pyspark.sql.html#pyspark.sql.DataFrameNaFunctions

Missing Values

- `column.isNull()`
- `dataframe.fillna()`

```
df.filter(df_dates['students_reached'].isNull()).select('students_reached', 'funding_status').collect()
```

```
[Row(students_reached=None, funding_status=u'completed'),
 Row(students_reached=None, funding_status=u'completed'),
 Row(students_reached=None, funding_status=u'expired'),
 Row(students_reached=None, funding_status=u'completed'),
                            ...
```

```
df_no_null = df.fillna(0, ['students_reached'])
```

Frequently Occurring Values

- `dataframe.freqItems(columns, support)`

Note: this is an approximate algorithm that **always** returns all the frequent items, but may contain false positives.

required minimum proportion of rows

```
freq_items = df.freqItems(['school_city', 'primary_focus_area', \
                           'grade_level', 'poverty_level','resource'], 0.7).collect()
```

```
freq_items[0]
```

```
Row(school_city_freqItems=[u'Los Angeles'], primary_focus_area_freqItems=[u'Literacy & Language'], grade_level_freqIt
ems=[u'Grades PreK-2'], poverty_level_freqItems=[u'highest poverty'], resource_freqItems=[u'Supplies'])
```

http://dl.acm.org/citation.cfm?doid=762471.762473

Summary Statistics

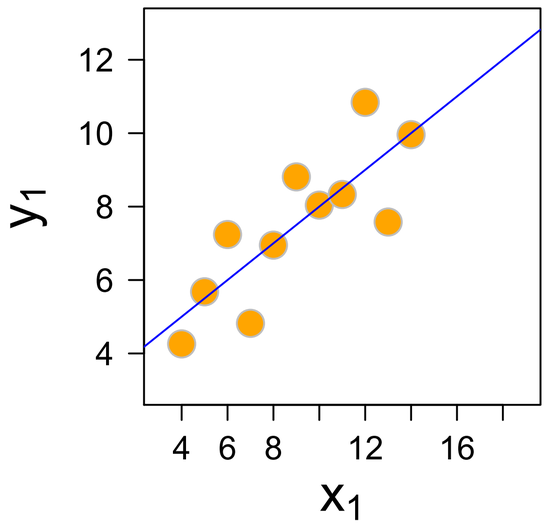
- `dataframe.describe(column_name)`

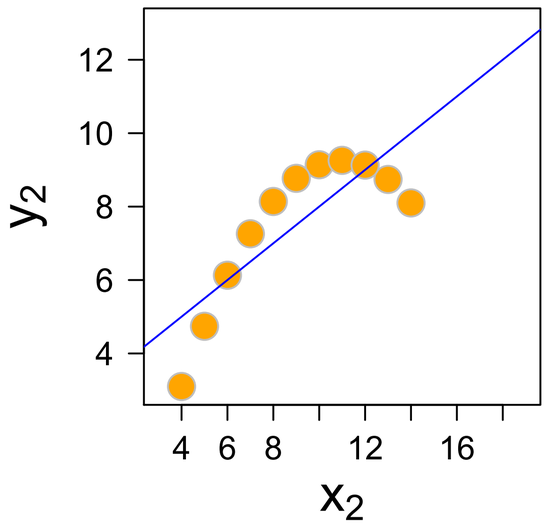
```
df.select('total_donations', 'num_donors', 'students_reached', \
                df_dates['total_price_excluding_optional_support'].alias('p_exclude'), \
                df_dates['total_price_including_optional_support'].alias('p_include')) \
  .describe().show()
```

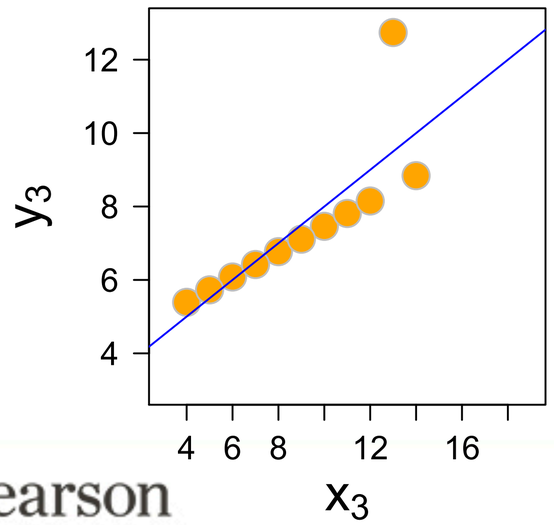
```
+-------+-----------------+-----------------+-----------------+------------------+-----------------+
|summary|  total_donations|       num_donors| students_reached|         p_exclude|         p_include|
+-------+-----------------+-----------------+-----------------+------------------+-----------------+
|  count|           771929|           771929|           771779|            771929|           771929|
|   mean|370.85023398481707|4.264279486843997|96.71620114048193| 569.6223687446723| 676.180708551764|
| stddev| 733.4647726421459|6.132976060232441|2118.592960253374|11763.955807309705|14344.347534777195|
|    min|              0.0|              0.0|              0.0|               0.0|              0.0|
|    max|         244778.0|            521.0|         999999.0|       1.0250017E7|       1.2500021E7|
+-------+-----------------+-----------------+-----------------+------------------+-----------------+
```

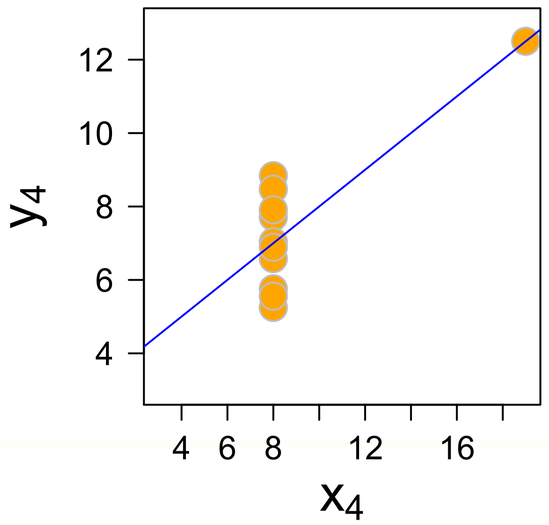
Interlude: Sometimes numbers aren’t enough!

Anscombe's Quartet









Mean (x)	9
Sample Variance (x)	11
Mean (y)	7.50
Sample Variance (y)	4.127
Correlation	0.816
Linear Regression	y = 3.00 + 0.500x

Distributions

RDD

- `rdd.histogram()`
- `rdd.stats()`

DataFrame

- `dataframe.groupby('column_name').count()`
- `dataframe.describe('column_name')`

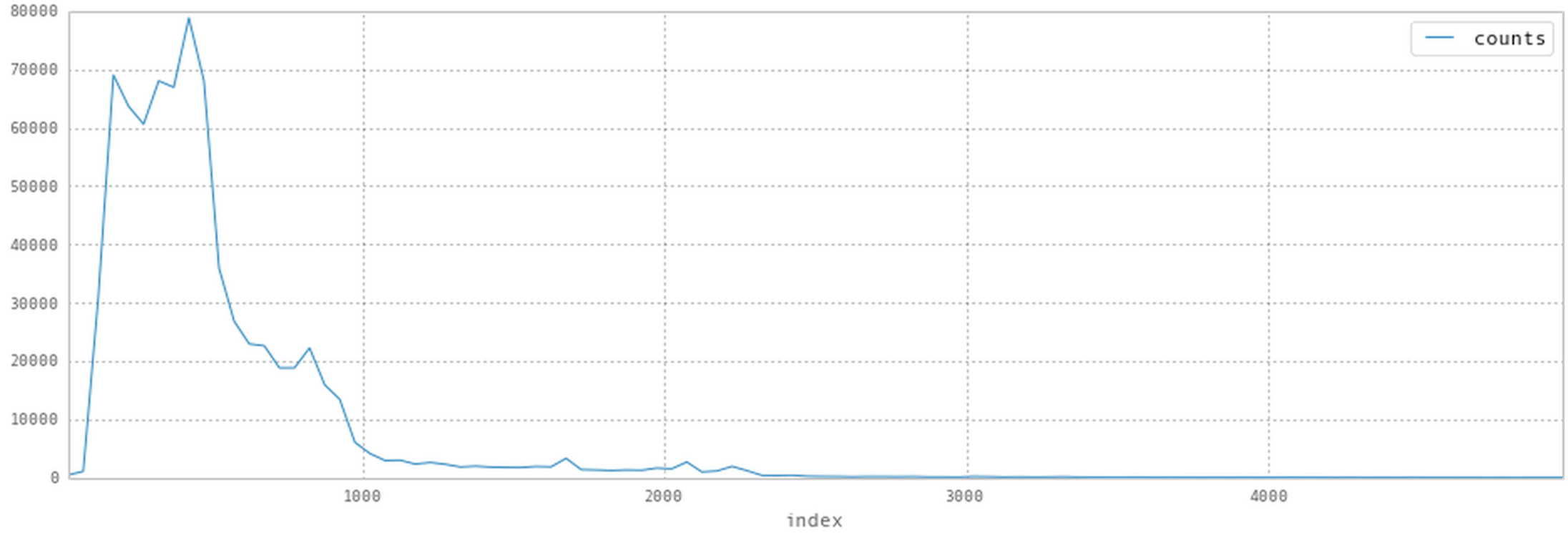
```
price_rdd = df_no_null.select('total_price_excluding_optional_support').rdd.map(lambda r: r.asDict().values()[0])
```

```
def plot_rdd_hist(hist):
    idx = []

    for i in range(len(hist[0]) - 1):
        idx.append((hist[0][i] + hist[0][i+1])/ 2)

    pd.DataFrame({'counts': hist[1], 'index': idx}).set_index('index').plot(figsize=(16,5))
```

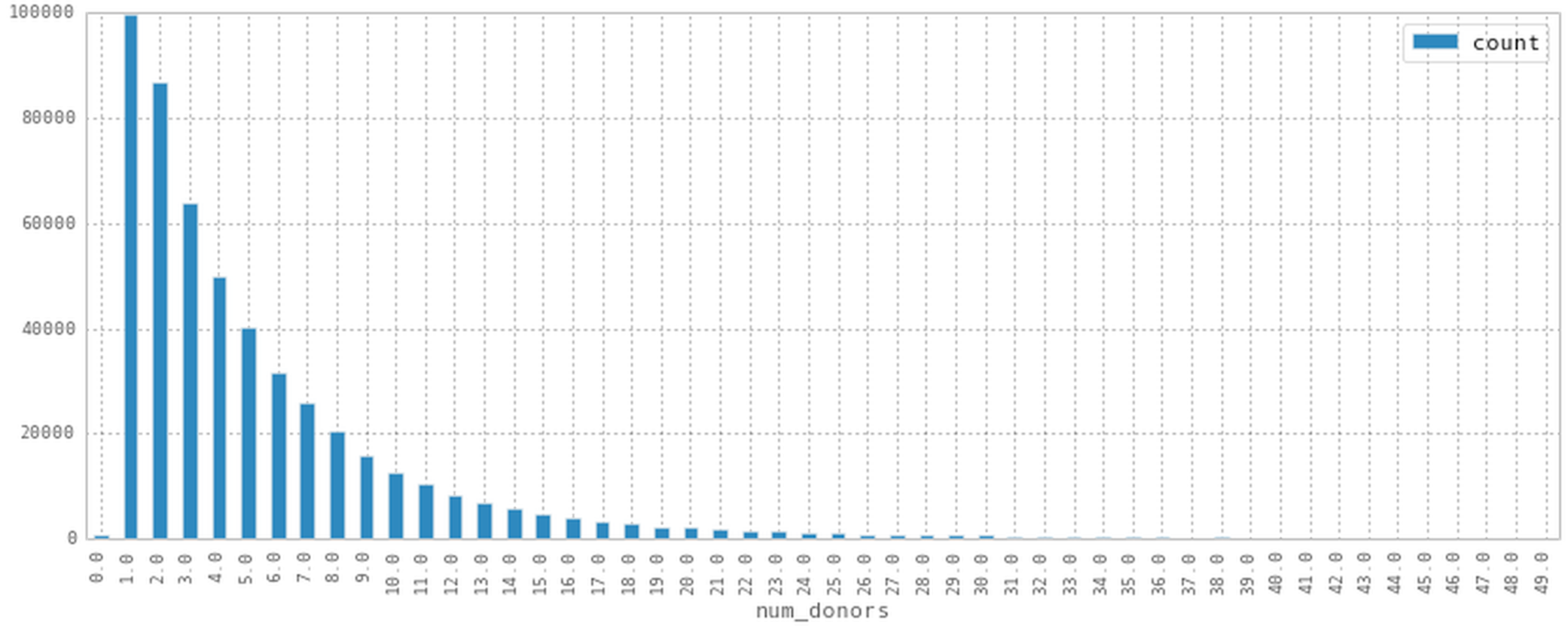
```
plot_rdd_hist(price_rdd.filter(lambda x: x < 5000).histogram(100))
```



```
def spark_histogram(df, column):
    donor_counts = df.groupby(column).count()
    donor_df = donor_counts.toPandas()
    donor_df[column] = donor_df.num_donors.astype(float)
    return donor_df.sort(column).set_index(column).iloc[:50,:].plot(kind='bar', figsize=(14,5))
```

```
spark_histogram(df_complete, 'num_donors')
```

```
<matplotlib.axes._subplots.AxesSubplot at 0x113b2be50>
```

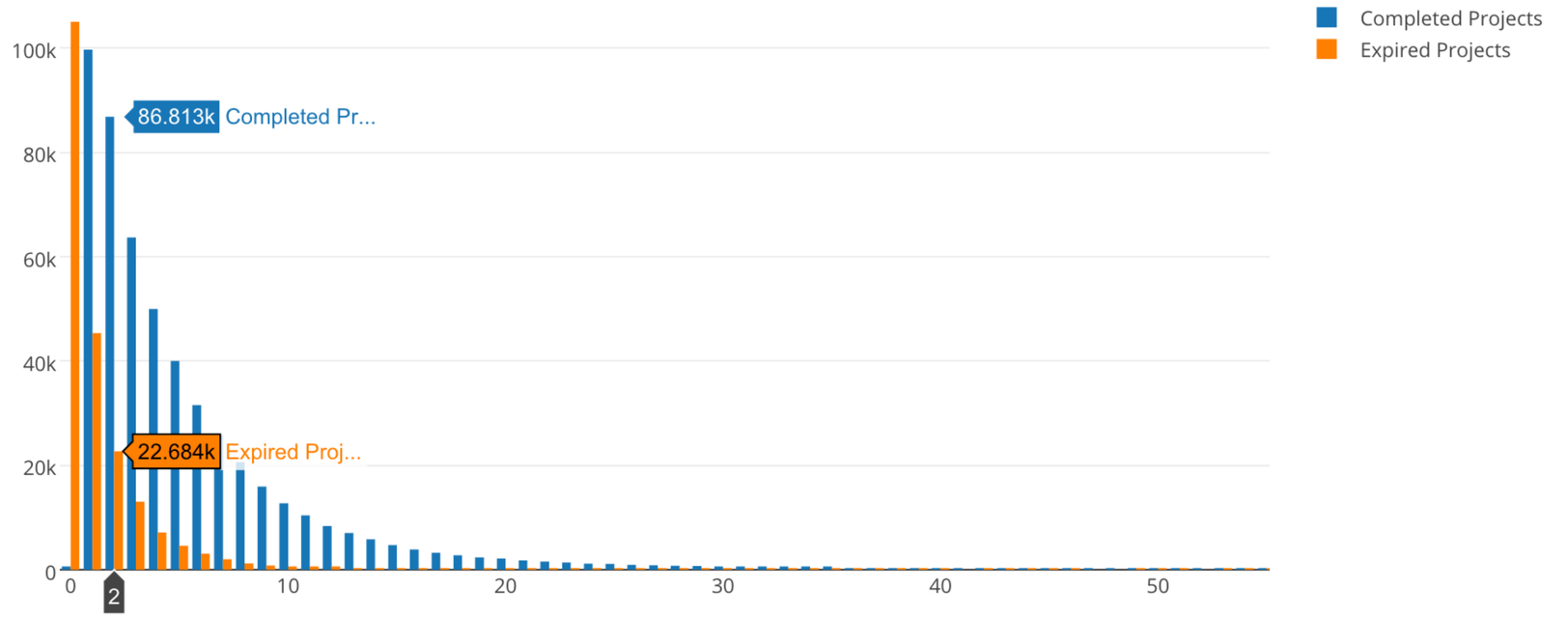


```
complete = df_complete.groupby('num_donors').count().toPandas()
expired = df_expired.groupby('num_donors').count().toPandas()
```

```
# And if we want an interactive plot, we can use a tool like plotly
# pip install plotly
import plotly.plotly as py
import plotly.tools as tls
from plotly.graph_objs import *

data = Data([
        Bar(x=complete['num_donors'], y= complete['count'], name="Completed Projects"),
        Bar(x=expired['num_donors'], y = expired['count'] , name="Expired Projects")
    ])

py.iplot(data)
```



Interactions

- dataframe.crosstab()
- dataframe.corr()

```
df_no_null.stat.corr('total_price_excluding_optional_support', 'num_donors')
```

```
0.007004254706419042
```

```
df_no_null.stat.corr('total_price_excluding_optional_support', 'students_reached')
```

```
0.0006159991686679948
```

```
df_no_null.stat.corr('total_price_excluding_optional_support', 'total_price_including_optional_support')
```

```
0.9999972199123168
```

```
df_dates.crosstab('resource_type', 'funding_status').show()
df_dates.crosstab('primary_focus_area', 'resource_type').show()
```

```
+----------------------------+-----+---------+-----------+-------+
|resource_type_funding_status| live|completed|reallocated|expired|
+----------------------------+-----+---------+-----------+-------+
|                        null|    2|       28|          0|     18|
|                       Other| 4542|    54610|        747|  22550|
|                       Books| 5982|   118810|       1527|  34554|
|                    Visitors|  102|      806|          6|    341|
|                    Supplies|11939|   185870|       2602|  63406|
|                       Trips|  347|     4381|         62|   1474|
|                  Technology|18957|   150500|       2256|  85510|
+----------------------------+-----+---------+-----------+-------+
```

```
+------------------------------+-----+--------+-----+----------+------+--------+----+
|primary_focus_area_resource_type|Trips|Visitors|Other|Technology| Books|Supplies|null|
+------------------------------+-----+--------+-----+----------+------+--------+----+
|              Literacy & Language|  630|     228|32795|    109605|127282|   75924|   4|
|                          null|    0|       0|    0|         0|     1|       0|  41|
|             Applied Learning| 1197|     104| 9429|     17869|  4863|   22596|   0|
|               Math & Science| 1902|     323|16353|     75189| 11746|   89101|   3|
|             Music & The Arts|  947|     441| 8305|     19289|  2883|   37804|   0|
|              Health & Sports|  159|      54| 4633|      3054|   432|   12970|   0|
|                 Special Needs|  241|      32| 7636|     19359|  4112|   17151|   0|
|             History & Civics| 1188|      73| 3298|     12858|  9554|    8271|   0|
+------------------------------+-----+--------+-----+----------+------+--------+----+
```

Review

- Interactive REPL
- Rapid computation (especially aggregates) on large amounts of data
- High level abstractions for efficient querying of data
- “Condense” data for easier local exploration and visualization

Natural Language Processing

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[1, 3, 1, 1, 2, 0, 1, 0]
[0, 1, 4, 0, 0, 1, 1, 1]
[3, 0, 1, 1, 2, 2, 3, 2]
[0, 1, 1, 1, 0, 3, 2, 3]
[1, 2, 1, 2, 2, 0, 0, 0]
[1, 0, 1, 1, 0, 1, 1, 1]
[0, 2, 0, 0, 2, 2, 0, 0]
[1, 1, 1, 1, 0, 1, 1, 1]

The Unreasonable Effectiveness of Data

[Banko and Brill, 2001]

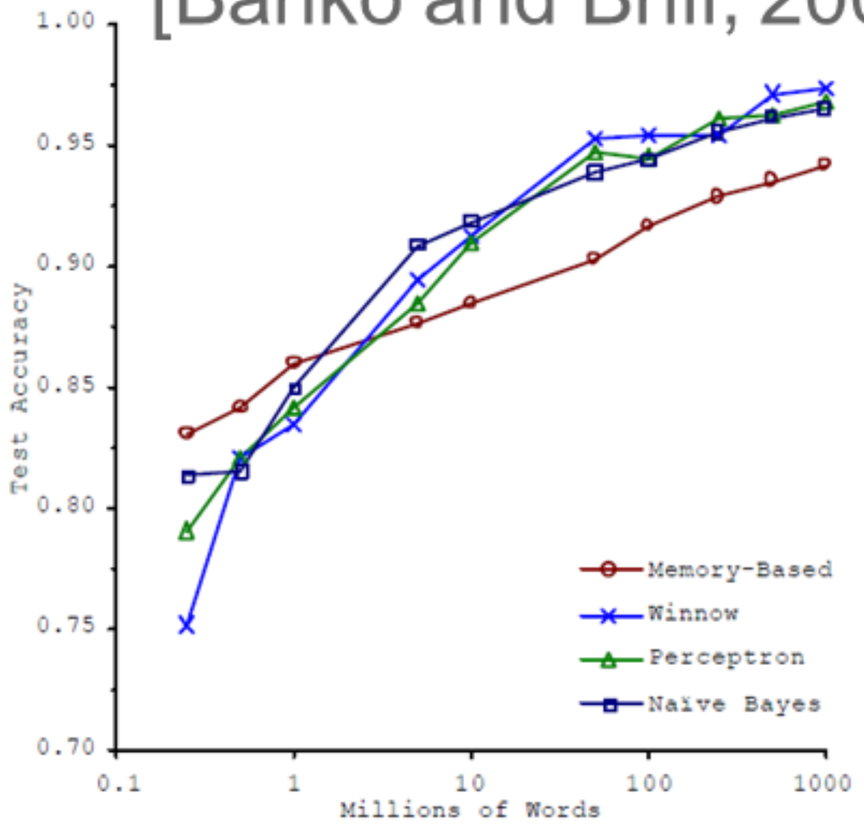


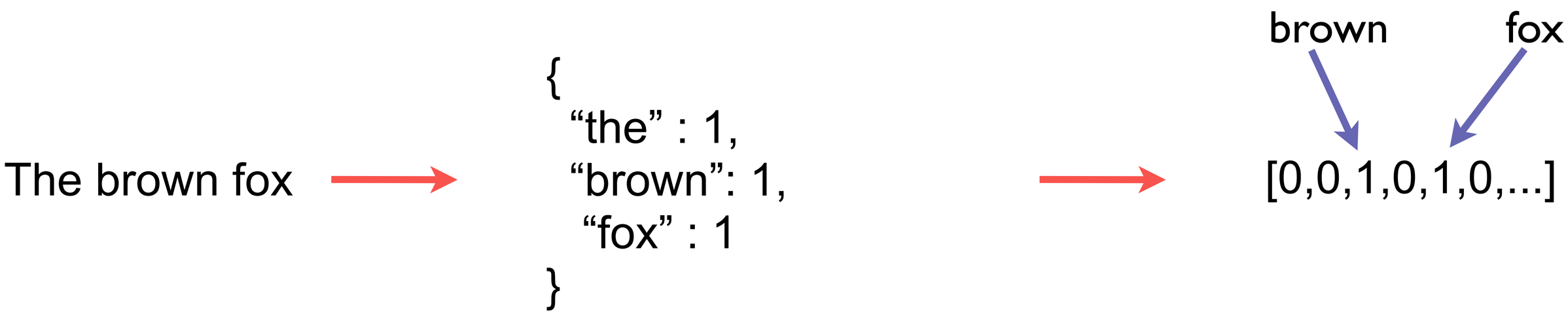
Figure 1. Learning Curves for Confusion Set Disambiguation

Source: https://www.microsoft.com/en-us/research/publication/scaling-to-very-very-large-corpora-for-natural-language-disambiguation/

Bag of Words

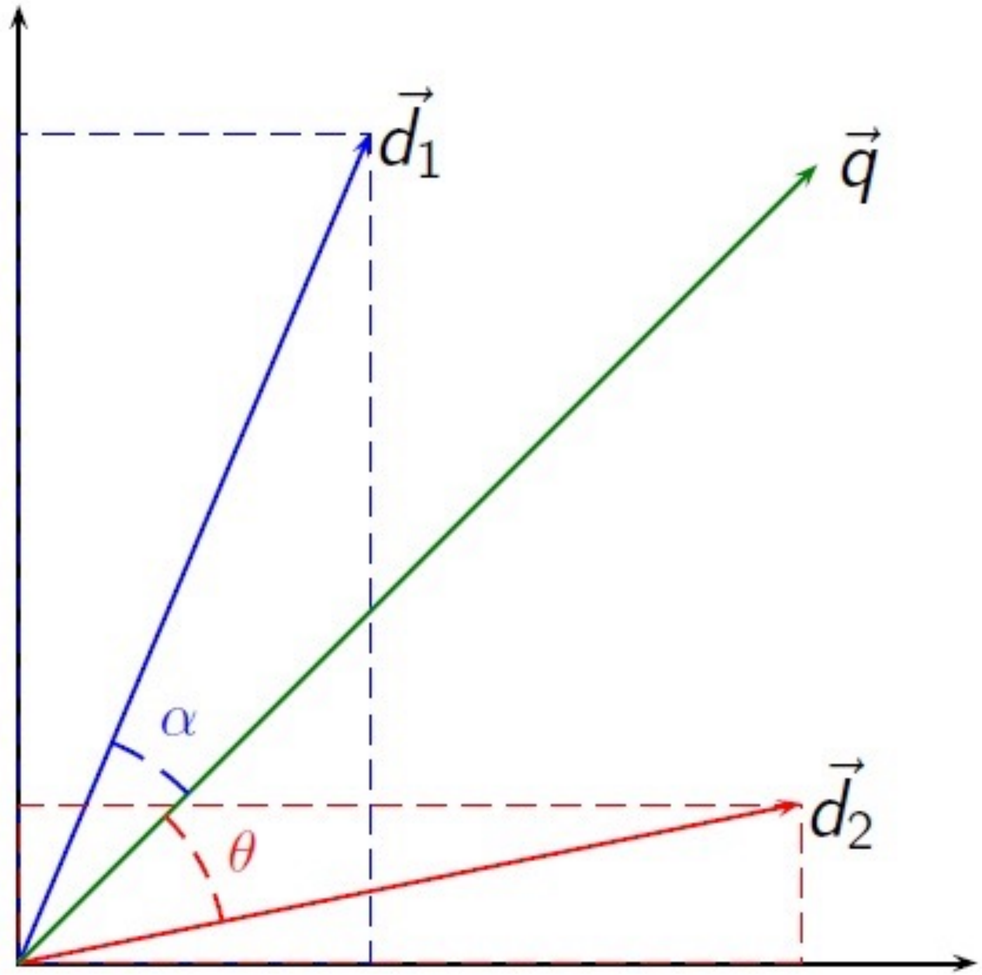
- **Document:** Single row of data/corpus
- **Corpus:** Entire set of all documents
- **Vocabulary:** Set of all words in corpus
- **Vector:** Mathematical representation of document (counts of word occurrences)

Bag of Words


The brown fox
{
"the" : 1,
"brown": 1,
"fox" : 1
}
brown
fox
[0,0,1,0,1,0,...]
Tokenization
Vectorization
original document
dictionary of word counts
feature vector

Vector Space Model

Similarity is a measure of “distance”

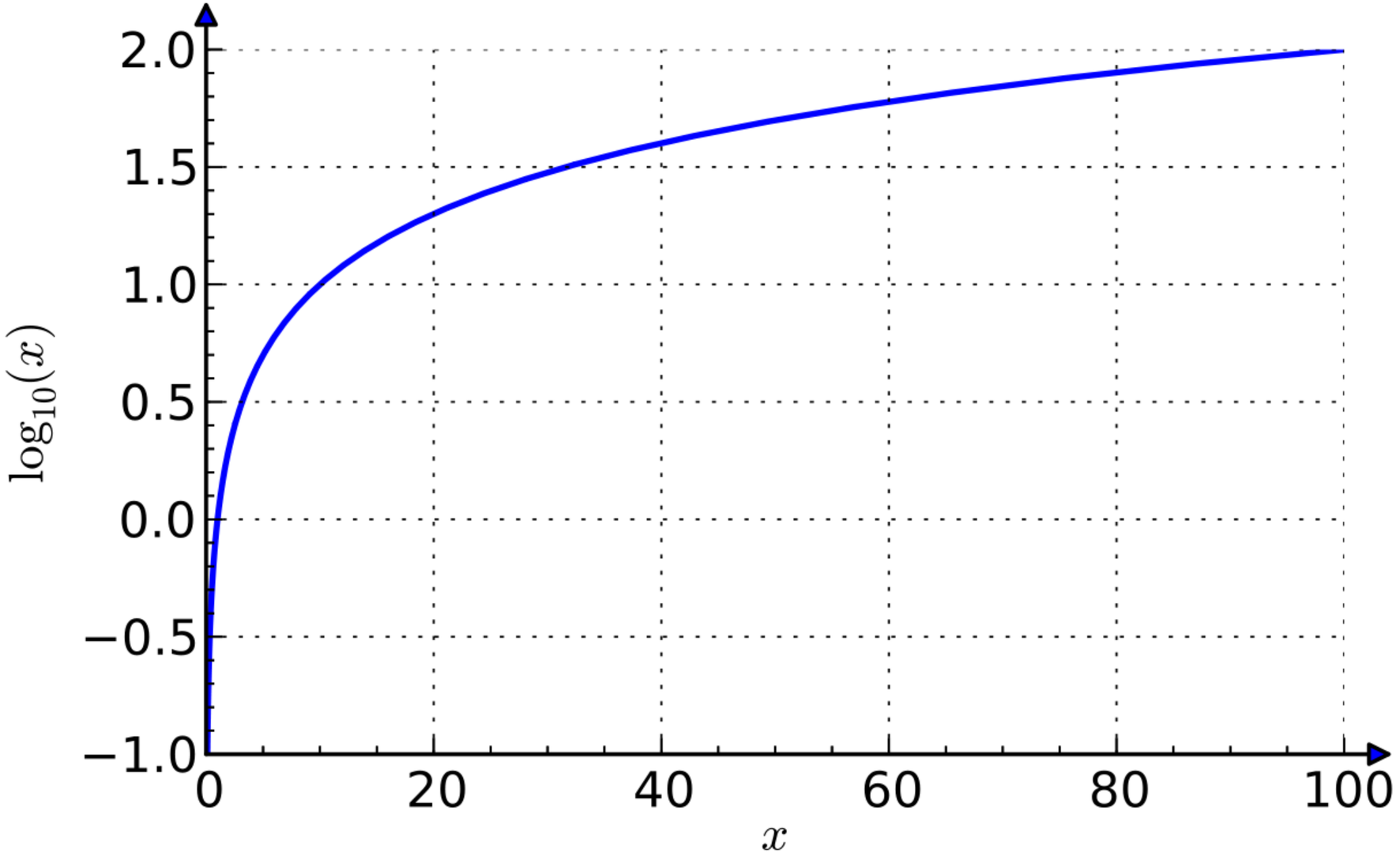


TF-IDF

- Measure of discriminatory power of word (feature)
- Highest when term occurs many times in a small number of documents
- Lowest when term occurs few times in document or many times in corpus
- Useful for information retrieval (queries) and keyword extraction (among other things)

$$tf(t,d) = \frac{f_d(t)}{|d|} \qquad idf(t,D) = \log\left(\frac{|D|}{|\{d \in D : t \in d\}|}\right)$$

TF-IDF



TF-IDF

Most Common

```
idf[:50]
```

```
[(u'students', 0.014067384597943282),
 (u'I', 0.15305316750494943),
 (u'school', 0.17010493952495984),
 (u'My', 0.3397655206814591),
 (u'The', 0.4149133167820112),
 (u'help', 0.4188088461791251),
 (u'classroom', 0.5361023876769617),
 (u'learning', 0.5748186189046272),
 (u'need', 0.5820538952580256),
 (u'They', 0.5941434194555928),
 (u'learn', 0.6187002265438729),
 (u'able', 0.7452815794748304),
 (u'use', 0.7494117483916651),
 (u"'", 0.755060153205684),
 (u'We', 0.7552806889430156),
 (u'This', 0.7749201702459683),
 (u'class', 0.7913652190100225),
 (u'would', 0.8149828303863013),
 (u'make', 0.8239845109910496),
 (u'many', 0.8273389184929604),
```

Least Common

```
idf[:-50:-1]
```

```
[(u'beer', 10.378594025517652),
 (u'worsen', 10.378594025517652),
 (u'theorist', 10.378594025517652),
 (u'Beneath', 10.378594025517652),
 (u'.how', 10.378594025517652),
 (u'unchanged', 10.378594025517652),
 (u'lessons-', 10.378594025517652),
 (u'on-stage', 10.378594025517652),
 (u'interactiveness', 10.378594025517652),
 (u'GoogleEarth', 10.378594025517652),
 (u'peers\u2019', 10.378594025517652),
 (u'pre-schools', 10.378594025517652),
 (u'PER', 10.378594025517652),
 (u'Davies', 10.378594025517652),
 (u'Spalding', 10.378594025517652),
 (u'7:15am', 10.378594025517652),
 (u'geneticists', 10.378594025517652),
 (u'20-year-old', 10.378594025517652),
 (u'inservice', 10.378594025517652),
 (u'Conquering', 10.378594025517652),
```

```
top_n = 10
summary = bag_of_words.map(lambda x: map(lambda idx: broadcast_idf.value[idx][0], np.argsort(x)[::-1][:top_n]))
```

```
summary.take(15)
```

```
[[u'science',
  u'Outreach',
  u'17-21',
  u'one-year',
  u'resource',
  u'magazine',
  u'periodical',
  u'http',
  u'York',
  u'competency'],
 [u'Worlds',
  u'Hidden',
  u'microscopes',
  u'cell',
  u'stressing',
  u'6th',
  u'single',
  u'cluster',
  u'intense',
  u'organisms'],
 [u'corner',
  u'Harlem',
  u'calming',
  u'rug',
  u'soft',
  u'world.In',
  u'began',
  u'populate',
  u'putting',
  u'stain'],
 [u'Music',
  u'music',
  u'Appreciation',
```

Summarization