Applied Data Analysis (CS401)

Lecture 2
Handling data
28 Sep 2022

EPFL

Robert West

dlab

Announcements

- **Register** your teams (4 people) here by Fri 7 Oct
  - Each team member must individually complete the form!
- **Project milestone P1** to be released this Fri, due Fri 14 Oct
- **First quiz** (previously called "~~Q0~~", now "Q1"*) to be held in this Friday's lab session
  - Test run, to make sure everything works smoothly
  - Won't count towards grade
- **Friday's lab session:**
  - Intro to Pandas (very important for Homework H1 and rest of course)

* This way, Q*i* is always about material from week *i*.

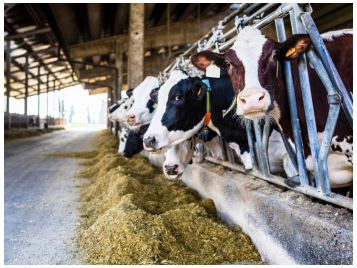
Feedback

Give us feedback on this lecture here:
https://go.epfl.ch/ada2022-lec2-feedback

Feedback form available for each lecture and lab session

- What did you (not) like about this lecture?
- What was (not) well explained?
- On what would you like more (fewer) details?
- Is it nicer to follow the lecture online or offline?
- …

Cooking with data

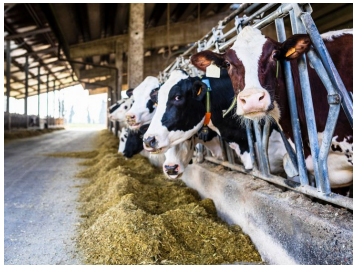


Part 2:
Data sources

Part 1:
Data models

Part 3:
Data wrangling

Cooking with data



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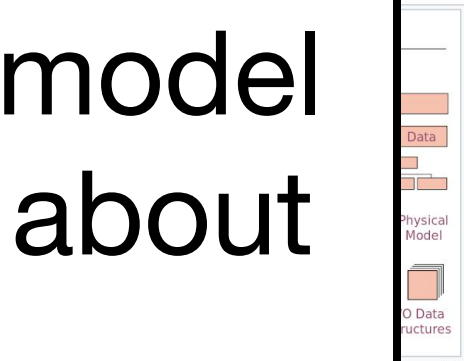
Data model

From Wikipedia, the free encyclopedia

A **data model** (or **datamodel**)[1][2][3][4][5] is an abstract model that organizes elements of data and standardizes how they relate to one another and to the properties of real-world entities. For instance, a data model may specify that the data element representing a car be composed of a number of other elements which, in turn, represent the color and size of the car and define its owner.

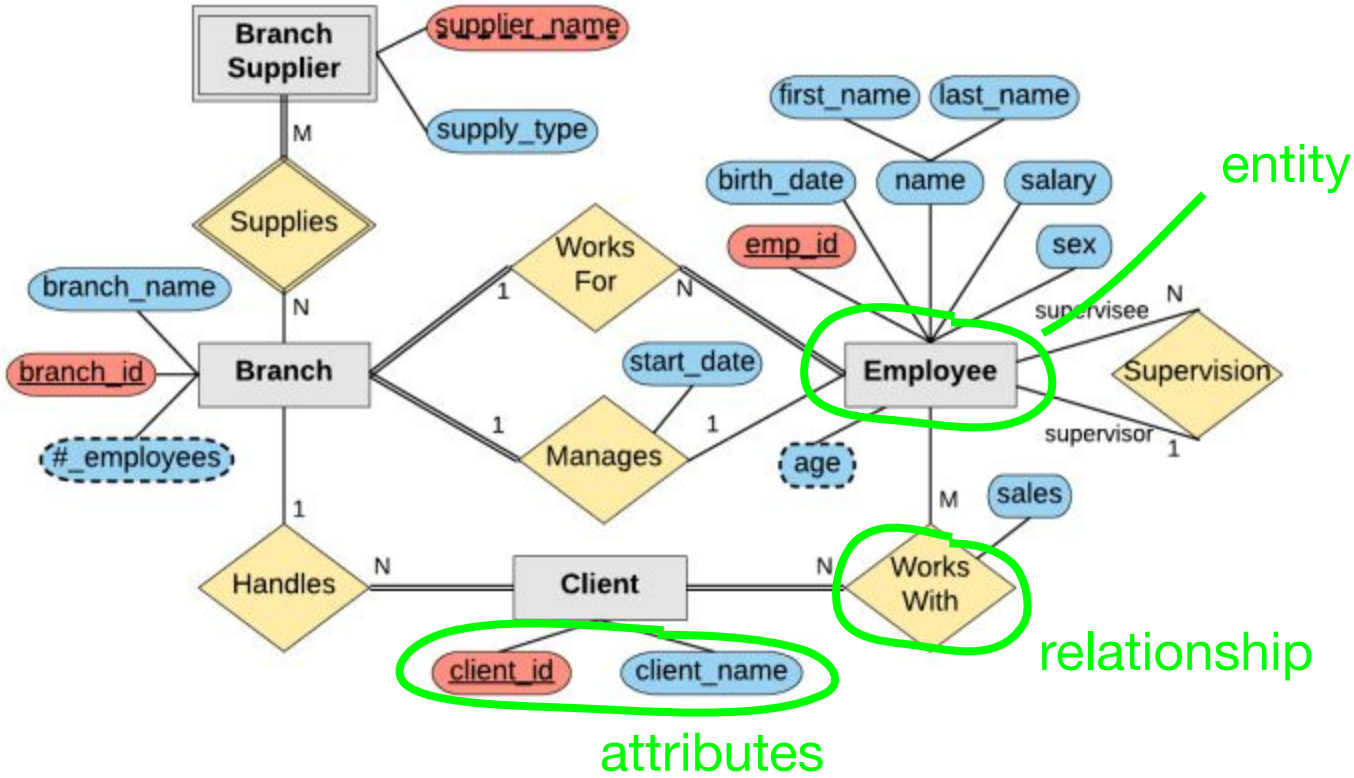
The term **data model** can refer to two distinct but closely related concepts. Sometimes it refers to an abstract formalization of the objects and relationships found in a particular application domain: for example the customers, products, and orders found in a manufacturing organization. At other times it refers to the set of concepts used in defining such formalizations: for example concepts such as entities, attributes, relations, or

Bob's definition: A data model specifies how you think about the world



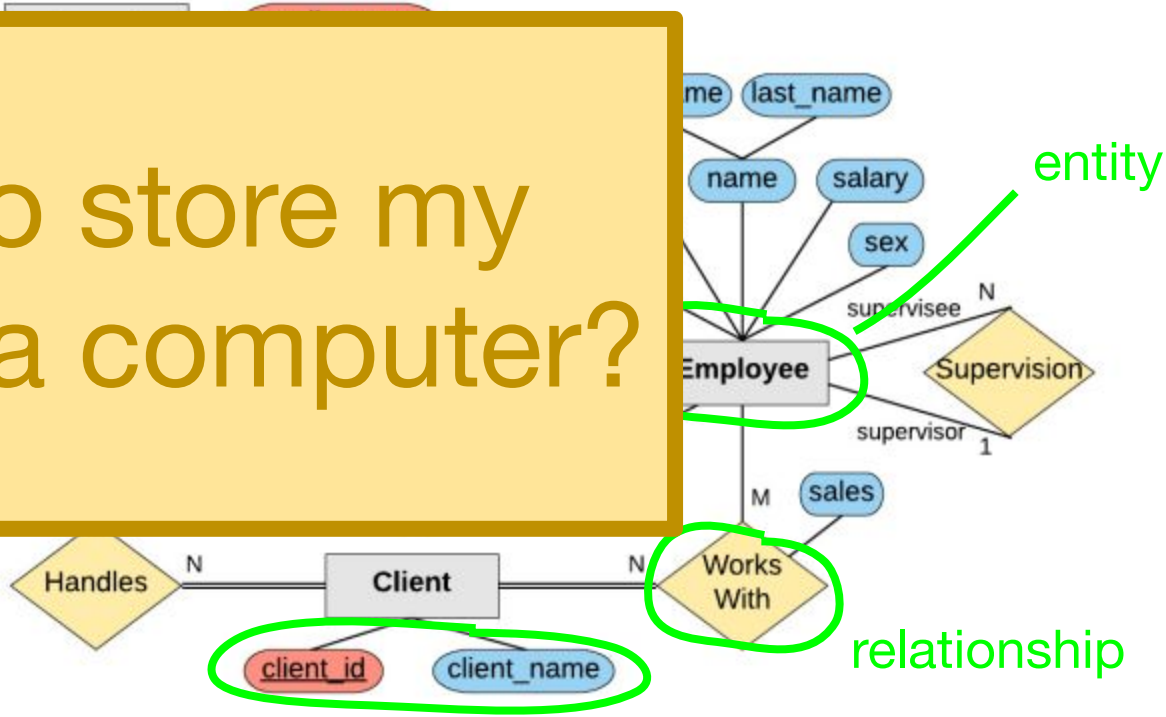
functional specification to aid a computer software make-or-buy decision. The figure is an example of the interaction between process and data models.[6]

Q: “How do you think about the world?”
A: “See my entity–relationship diagram!”



Q: “How do you think about the world?”
A: “See my entity–relationship diagram!”

How to store my data on a computer?



Q1: “How should I store my data on a computer?”
Q2: “How do I think about the world?”

- “The world is simple: one type of entity, all with the same attributes”
  → **Flat model**

```
66.249.65.107 - -  08/Oct/2007:04:54:20 -0400] "GET /support.html
HTTP/1.1" 200 1117  "-" "Mozilla/5.0 (compatible; Googlebot/2.1;
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```
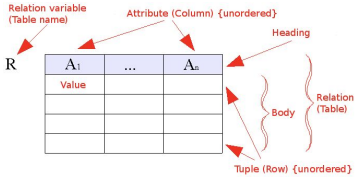
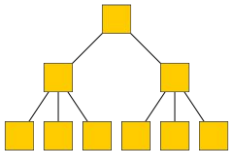
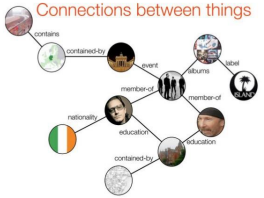

- “The world contains many types of entities, connected by relationships”
  → **Relational model**



- “The world is a hierarchy of entities”
  → **Document model**



- “The world is a complex network of entities”
  → **Network model**



Flat model

- Example: log files; e.g., Apache web server (`httpd`)
  - Entities = requests from clients to server

```
66.249.65.107 - - [08/Oct/2007:04:54:20 -0400] "GET /support.html
HTTP/1.1" 200 11179 "-" "Mozilla/5.0 (compatible; Googlebot/2.1;
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111.111.111.111 - - [08/Oct/2007:11:17:55 -0400] "GET / HTTP/1.1" 200
10801
"http://www.google.com/search?q=in+love+with+ada+lovelace+what+to+do&ie=ut
f-8&oe=utf-8&aq=t&rls=org.mozilla:en-US:official&client=firefox-a"
"Mozilla/5.0 (Windows; U; Windows NT 5.2; en-US; rv:1.8.1.7)
Gecko/20070914 Firefox/2.0.0.7"
```

- Another common format: CSV (“comma-separated vector”)

Q1: “How should I store my data on a computer?”
Q2: “How do I think about the world?”

- “The world is simple: one type of entity, all with the same attributes”
  → **Flat model**

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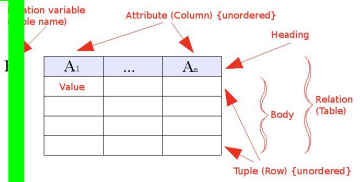
- “The world contains many types of entities, connected by relationships”
  → **Relational model**



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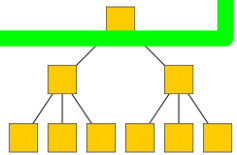
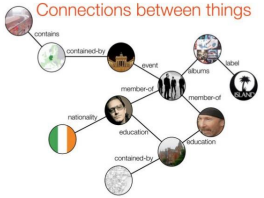


- “The world is a complex network of entities”
  → **Network model**



Relational model

- "The world contains many types of entities, connected by relationships"
- The relational model is ubiquitous:
  - MySQL, PostgreSQL, Oracle, DB2, SQLite, …
  - You use it many times every day
- Data represented as tables ("relations") describing
  - entities,
  - relationships between entities

id	name
1	Bush
2	Trump
3	Obama

president	successor
1	3
3	2

Processing data in the relational model: SQL

- *Declarative* language for core data manipulations
- You think about what you want, not how to compute it

Imperative

```
//dogs = [{name: 'Fido', owner_id: 1}, {...}, ... ]
//owners = [{id: 1, name: 'Bob'}, {...}, ...]

var dogsWithOwners = []
var dog, owner

for(var di=0; di < dogs.length; di++) {
  dog = dogs[di]

  for(var oi=0; oi < owners.length; oi++) {
    owner = owners[oi]
    if (owner && dog.owner_id == owner.id) {
      dogsWithOwners.push({
        dog: dog,
        owner: owner
      })
    }
  }}
}
```

Declarative

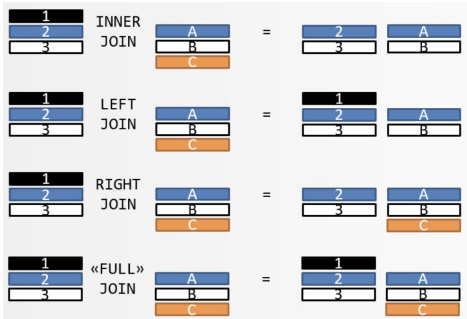
```
SELECT * from dogs
INNER JOIN owners
WHERE dogs.owner_id = owners.id
```

From: http://latentflip.com/imperative-vs-declarative/

SQL

```
SELECT * from dogs
INNER JOIN owners
WHERE dogs.owner_id = owners.id
```

- You should know basics of SQL
- Need a refresher? → Watch/do online tutorials!
- Key concepts:
  - Select (!), update, delete
  - Unique keys
  - Joins (inner, left outer, right outer, full)
  - Sorting
  - Aggregation (group by, count, min, max, avg, etc.)



POLLING TIME

- **“Have you worked with SQL joins?”**
- Scan QR code or go to https://web.speakup.info/room/join/66626

SQL implementations

etc.

```
#!/usr/bin/python

import MySQLdb

# Open database connection
db = MySQLdb.connect("localhost","testuser","test123","TESTDB" )

# prepare a cursor object using cursor() method
cursor = db.cursor()

sql = "SELECT * FROM EMPLOYEE \
       WHERE INCOME > '%d'" % (1000)
try:
   # Execute the SQL command
   cursor.execute(sql)
   # Fetch all the rows in a list of lists.
   results = cursor.fetchall()
   for row in results:
      fname = row[0]
      lname = row[1]
      age = row[2]
      sex = row[3]
      income = row[4]
      # Now print fetched result
      print "fname=%s,lname=%s,age=%d,sex=%s,income=%d" % \
             (fname, lname, age, sex, income )
except:
   print "Error: unable to fecth data"

# disconnect from server
db.close()
```

SQL and “SQL”

- The declarative-programming principles of SQL are widespread, even where it’s less obvious

“SQL”: Pandas (Python library)

- Similar to SQL (declarative), with additional elements of functional programming (map(), filter(), etc.)
- SQL “table” ←→ Pandas “DataFrame”
- Need intro? Come to Friday’s lab session!

Pandas vs. SQL

+ Pandas is lightweight and fast.

+ Natively Python, i.e., full SQL expressiveness plus the expressiveness of Python, especially for function evaluation.

+ Integration with plotting functions like Matplotlib.

- In Pandas, tables must fit into memory.

- No post-load indexing functionality: indices are built when a table is created.

- No transactions, journaling, etc. (matters for parallel applications)

- Large, complex joins are slower.

“SQL”: Unix command line

```
cat users.txt \
| awk ‘$2 >= 18 && $2 <= 25’ \
| join -1 1 -2 1 url_visits.txt - \
| cut -f 4 \
| sort \
| uniq -c \
| sort -k 1,1 -n -r \
| head -n 5
```

Q1: “How should I store my data on a computer?”
Q2: “How do I think about the world?”

- “The world is simple: one type of entity, all with the same attributes”
  → **Flat model**

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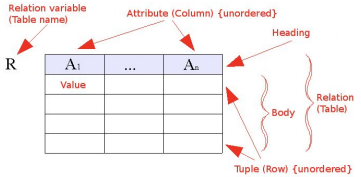

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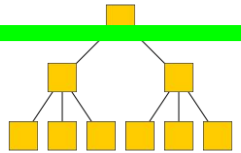

- “The world is a complex network of entities”
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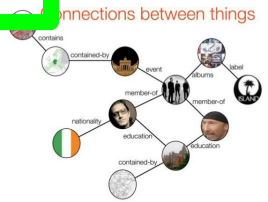

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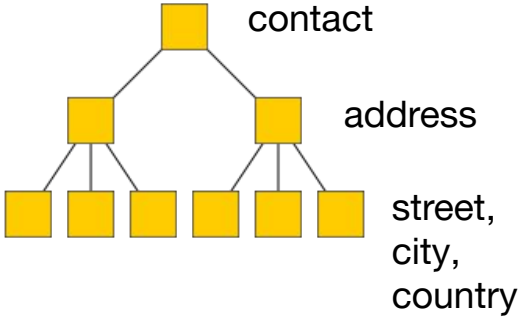

- "The world is a hierarchy of entities"
- XML format:

```
<contact>
   <id>656</id>
   <firstname>Chuck</firstname>
   <lastname>Smith</lastname>
   <phone>(123) 555-0178</phone>
   <phone>(890) 555-0133</phone>
   <address>
     <street>Rue de l'Ale 8</street>
     <city>Lausanne</city>
     <zip>1007</zip>
     <country>CH</country>
   </address>
</contact>
```

- JSON format:

```
contact: {
   id: 656,
   firstname: "Chuck",
   lastname: "Smith",
   phones: ["(123) 555-0178",
            "(890) 555-0133"],
   address: {
     street: "Rue de l'Ale 8",
     city: "Lausanne",
     zip: 1007,
     country: "CH"
   }
}
```

- Document model

```
<contact>
  <id>656</id>
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    <country>CH</country>
  </address>
</contact>
```

Think for a minute:

If we want to use a relational DB (e.g., MySQL) instead of XML, how can we store 2 phone numbers for the same person?

(Feel free to discuss with your neighbor.)

Solution to “Think for a minute”

- Document model

```
<contact>
  <id>656</id>
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  <lastname>Smith</lastname>
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  <phone>(890) 555-0133</phone>
  <address>
    <street>Rue de l’Ale 8</street>
    <city>Lausanne</city>
    <zip>1007</zip>
    <country>CH</country>
  </address>
</contact>
```

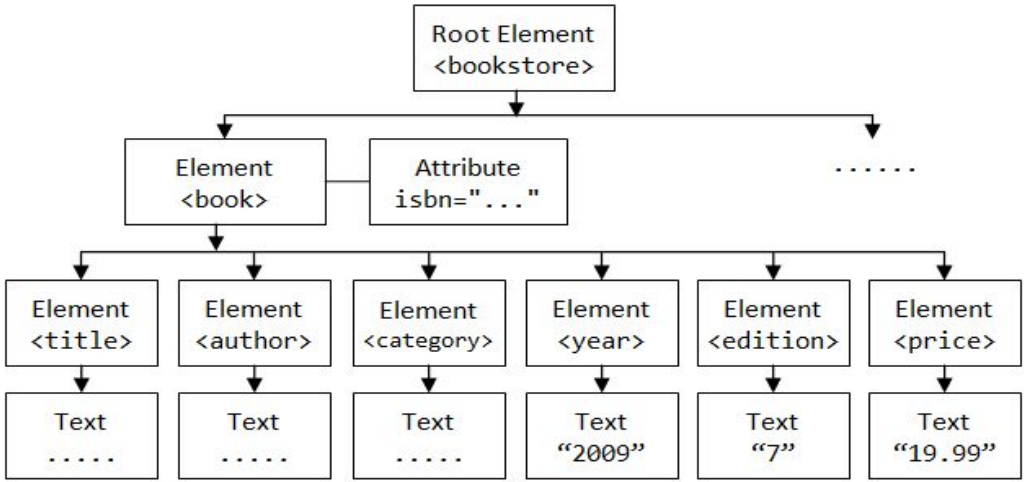
- Same in relational model

id	first name	...
656	Chuck	...
...	...	...

id	phone
656	(123) 555-0178
656	(890) 555-0133
...	...

Processing XML and JSON

- Document structure = tree
- Processing via tree traversal (depth- or breadth-first search)
- Or use proper query language, such as XQuery or jq



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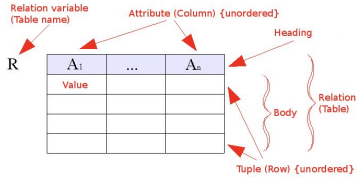

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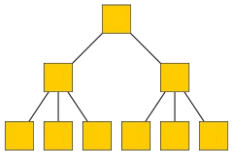
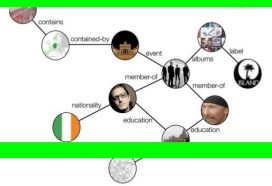
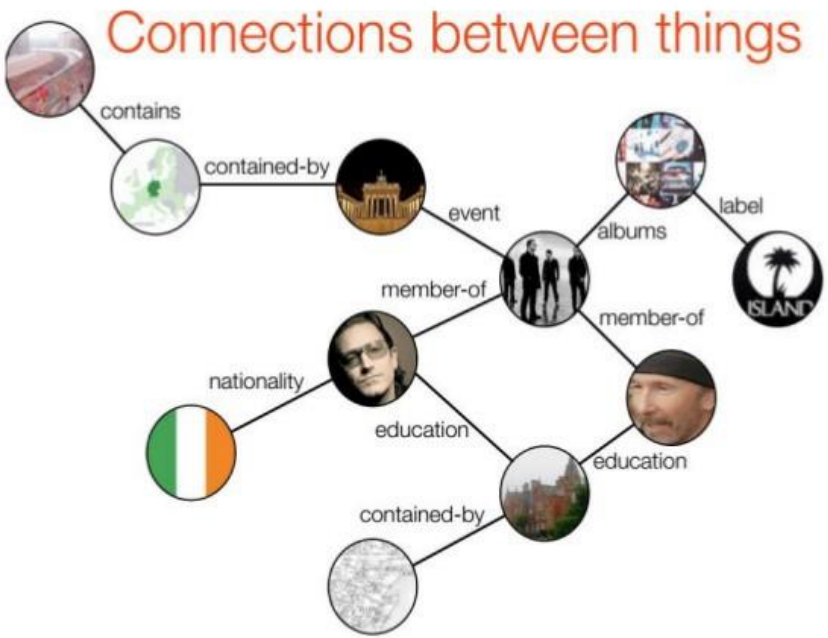


- “The world is a complex network of entities”
  → **Network model**



Network model

- “The world is a complex network of entities”

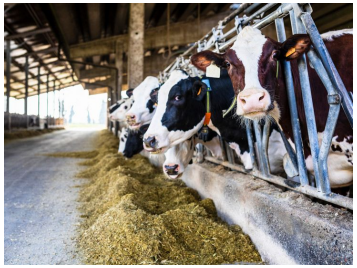


“How should I store my data on a computer?” —A word (or two) on binary formats

- Binary format often the key to performance, **avoiding expensive parsing**
- Modern binary formats support nested structures, various levels of schema enforcement, compression, etc.
- Python pickle, Java Serializable, Protocol Buffers (Google), Avro (supports schema evolution), Parquet (column-oriented), etc.

→ Consider converting to a binary format at the beginning of your processing pipeline (especially when using “big data”)

Cooking with data



Part 2:
Data sources

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Data sources at Web companies

Examples from Facebook

- Application databases
- Web server logs
- Client-side event logs
- API server logs
- Ad server logs
- Search server logs
- Advertisement landing page content
- Wikipedia
- Images and video

Structured data (with clear schema)

Semi-structured data ("self-describing" structure; CSV etc.)

Unstructured data

Another example: Wikipedia

- 300+ languages
- 42 million entities
- Mind-boggling richness of data

San Francisco

From Wikipedia, the free encyclopedia
(Redirected from San Francisco, California)

Coordinates: 37°47′N 122°25′W

This article is about the city and county in California. For other uses, see San Francisco (disambiguation).

San Francisco (initials **SF**[17]) (/ˌsæn frənˈsɪskoʊ/, Spanish for Saint Francis; Spanish: [san franˈsisko]), officially the **City and County of San Francisco**, is the cultural, commercial, and financial center of Northern California. The consolidated city-county covers an area of about 47.9 square miles (124 km²)[18] at the north end of the San Francisco Peninsula in the San Francisco Bay Area. It is the fourth-most populous city in California, and the 13th-most populous in the United States, with a 2016 census-estimated population of 870,887.[13] The population is projected to reach 1 million by 2033.[19]

San Francisco was founded on June 29, 1776, when colonists from Spain established Presidio of San Francisco at the Golden Gate and Mission San Francisco de Asís a few miles away, all named for St. Francis of Assisi.[1] The California Gold Rush of 1849 brought rapid growth, making it the largest city on the West Coast at the time. San Francisco became a consolidated city-county in 1856.[20] After three-quarters of the city was destroyed by the 1906 earthquake and fire,[21] San Francisco was quickly rebuilt, hosting the Panama-Pacific International Exposition nine years later. In World War II, San Francisco was a major port of embarkation for service members shipping out to the Pacific Theater.[22] It then became the birthplace of the United Nations in 1945.[23][24][25] After the war, the confluence of returning servicemen, massive immigration, liberalizing attitudes, along with the rise of the "hippie" counterculture, the Sexual Revolution, the Peace Movement growing from opposition to United States involvement in the Vietnam War, and other factors led to the Summer of Love and the gay rights movement, cementing San Francisco as a center of liberal activism in the United States. Politically, the city votes strongly along liberal Democratic Party lines.

A popular tourist destination,[26] San Francisco is known for its cool summers, fog, steep rolling hills, eclectic mix of architecture, and landmarks, including the Golden Gate Bridge, cable cars, the former Alcatraz Federal Penitentiary, Fisherman's Wharf, and its Chinatown district. San Francisco is also the headquarters of five major banking institutions and various other companies such as Levi Strauss & Co., Gap Inc., Fitbit, Salesforce.com, Dropbox, Reddit, Square, Inc., Dolby, Airbnb, Weebly, Pacific Gas and Electric Company, Yelp, Pinterest, Twitter, Uber, Lyft, Mozilla, Wikimedia Fo
home to number of educational and cultural institutions, such as the Univer
Museum, the San Francisco Museum of Modern Art, and the California Aca

San Francisco has several nicknames, including "The City by the Bay", "Go
City", and as well as older ones like "The City that Knows How", "Baghdad
City".[17] As of 2017, San Francisco is ranked high on world liveability ranki

Contents [hide]

San Francisco, California
Consolidated city-county
City and County of San Francisco

San Francisco and the Golden Gate Bridge from Marin Headlands

Flag

Seal

link

Location of San Francisco in California
Coordinates: 37°47′N 122°25′W

Country	United States
State	California

Learning resources from Wikiversity

Places adjacent to San Francisco [show]
v · t · e City and County of San Francisco [show]
Articles relating to the City and County of San Francisco [show]

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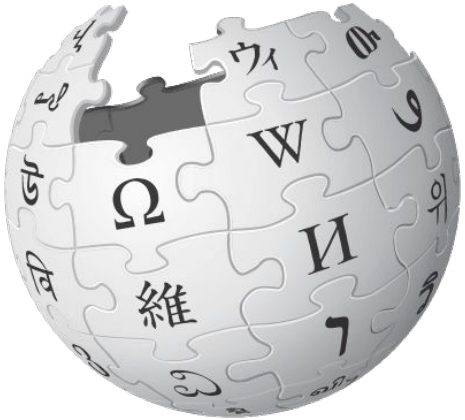
Categories: San Francisco | 1850 establishments in California | California counties | Cities in the San Francisco Bay Area | Consolidated city-counties in the United States | Counties in the San Francisco Bay Area | County seats in California | Hudson's Bay Company trading posts | Incorporated cities and towns in California | Populated coastal places in California | Populated places established in 1776 | Port cities and towns of the West Coast of the United States | Spanish mission settlements in North America

Wikipedia

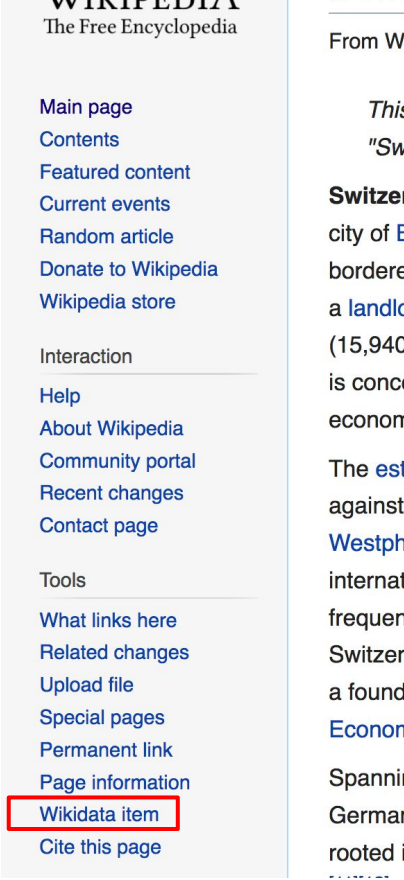


How to work with Wikipedia?

- XML dumps with wiki markup, SQL database dumps
- Issues: Unicode, size, recency, etc.
- To make your life easier:
  (1) Find projects on GitHub to help you
  (2) Use more structured versions (p.t.o.)

Wikidata

- “Database version” of Wikipedia
- {fr:Suisse, de:Schweiz, it:Svizzera, en:Switzerland, …} → Q39



Switzerland (Q39)

Main page
Community portal
Project chat
Create a new item
Recent changes
Random item
Query Service
Nearby
Help
Donate

Tools

What links here
Related changes
Special pages
Permanent link
Page information
Concept URI
Cite this page

federal republic in Western Europe edit

Swiss Confederation | CH | SUI | Suisse | Schweiz | Svizzera |

In more languages Configure

Language	Label	Description	Also known as
English	Switzerland	federal republic in Western Europe	Swiss Confederation CH SUI Suisse Schweiz Svizzera
German	Schweiz	Staat in Mitteleuropa	Schweizerische Eidgenossensc… Eidgenossenschaft CH SUI
Swiss German	Schwyz	No description defined	
French	Suisse	pays d'Europe	Confédération helvétique Confédération suisse CH SUI

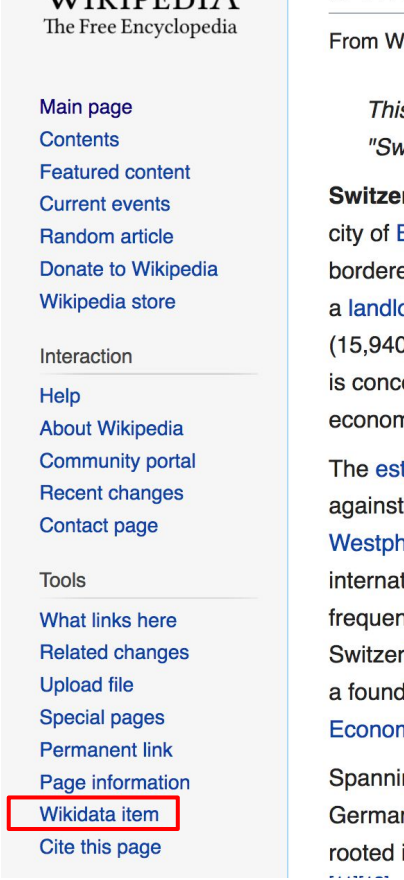
All entered languages

Statements

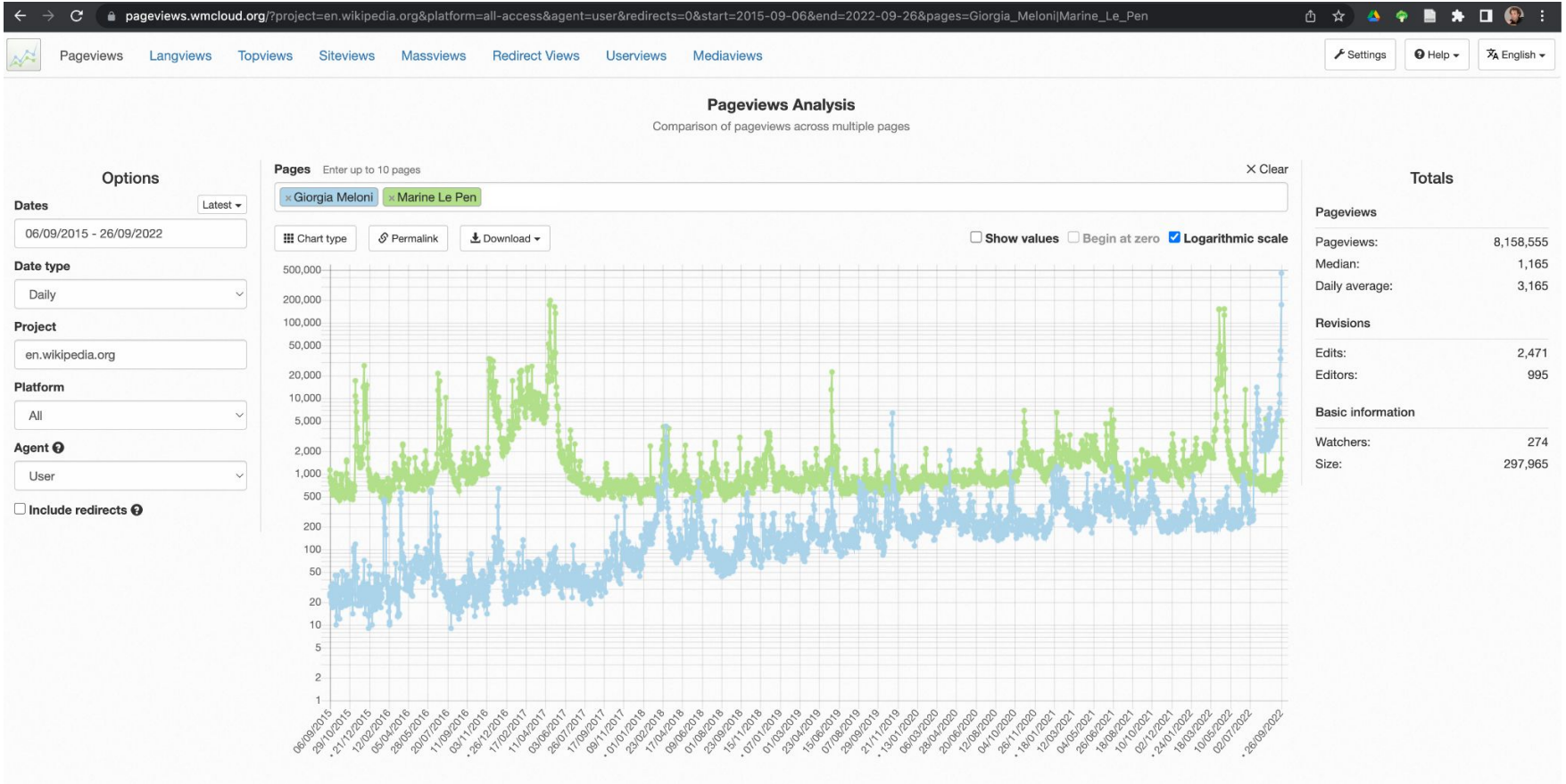
instance of	sovereign state 1 reference	edit
	country start time 12 September 1848 *Gregorian*	edit

Wikidata

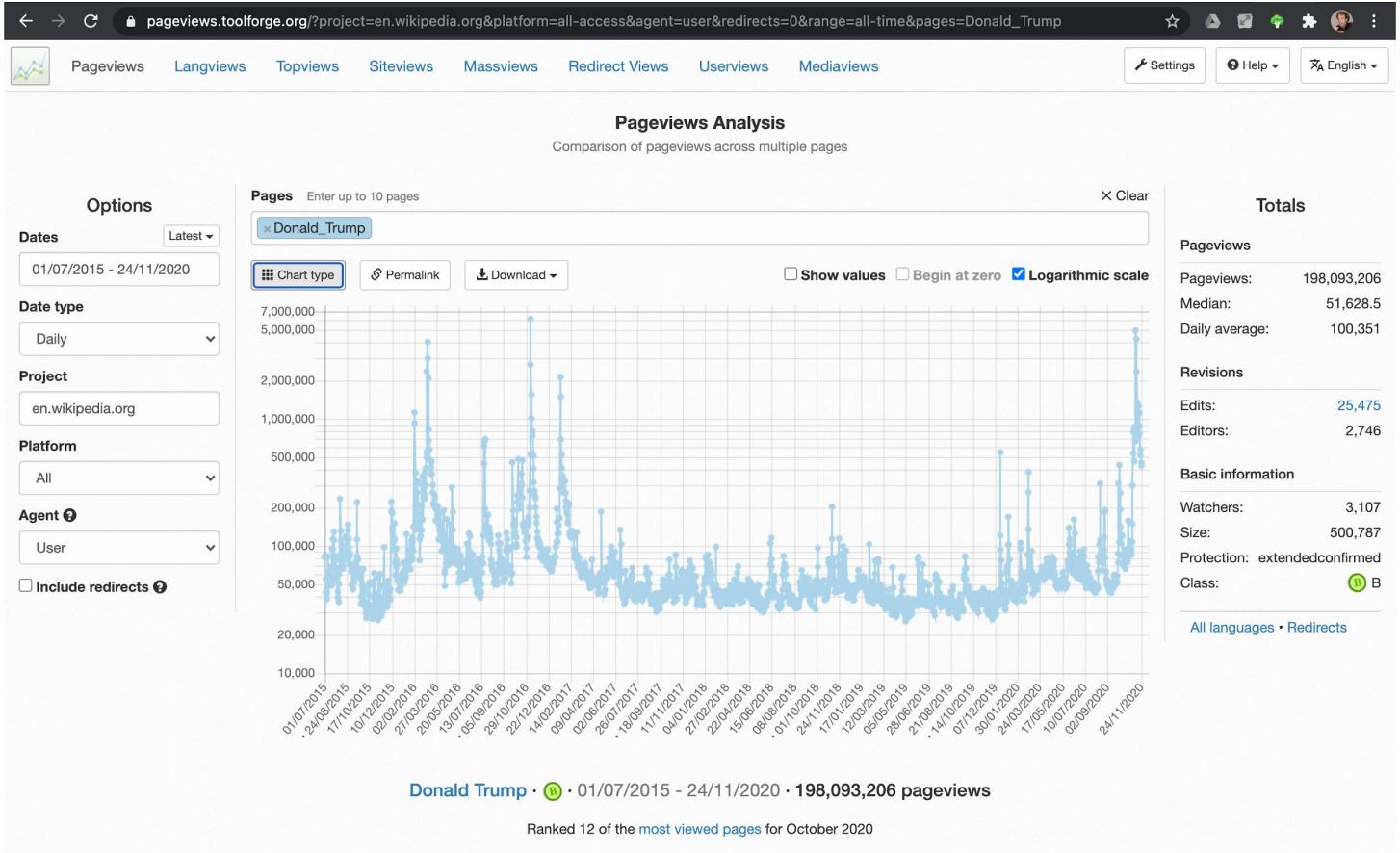
- “Database version” of Wikipedia
- {fr:Suisse, de:Schweiz, it:Svizzera, en:Switzerland, …} → Q39
- Both API access and full database dumps
- Available as
  - JSON (document model)
  - RDF (network model)



Wikipedia pageview logs



Wikipedia pageview logs



Crawling and processing webpages: HTML

Plenty of bulk-downloadable HTML data:

- Common Crawl dataset, about 1.82 billion web pages -- huge!
- (… but less than 0.1% of Google's Web crawl, as of 2015)
- 145 TB, hosted on Amazon S3, also available for download

… but if you need a specific website: use a **crawler/"spider"**: Apache Nutch, Storm, Heritrix 3, Scrapy, etc. (or simply wget…)

Useful HTML tools

Requests http://docs.python-requests.org/en/master/
An elegant and simple HTTP library for Python

Scrapy https://scrapy.org/
An open-source framework to build Web crawlers

Beautiful Soup http://www.crummy.com/software/BeautifulSoup/
A Python API for handling real HTML

Plain ol' /regular/expres*ion/s…

Schema.org: microformats for Web pages

- Nuggets of structured information embedded in (semantically) unstructured HTML

```
<div itemscope itemtype="http://schema.org/Movie">
  <h1 itemprop="name">Avatar</h1>
  <div itemprop="director" itemscope itemtype="http://schema.org/Person">
  Director: <span itemprop="name">James Cameron</span>
(born <time itemprop="birthDate" datetime="1954-08-16">August 16, 1954</time>)
  </div>
  <span itemprop="genre">Science fiction</span>
  <a href="../movies/avatar-theatrical-trailer.html" itemprop="trailer">Trailer</a>
</div>
```

Web services

- Most large web sites today actively discourage "screen-scraping" to get their content
- Instead: Web service APIs, for interoperable machine-to-machine interaction over a network
- The preferred way to get data from online sources
- Most common framework: REST
  - You request a URL from the server via HTTP
  - The server responds with a text file (e.g., JSON, XML, plain text)

REST example

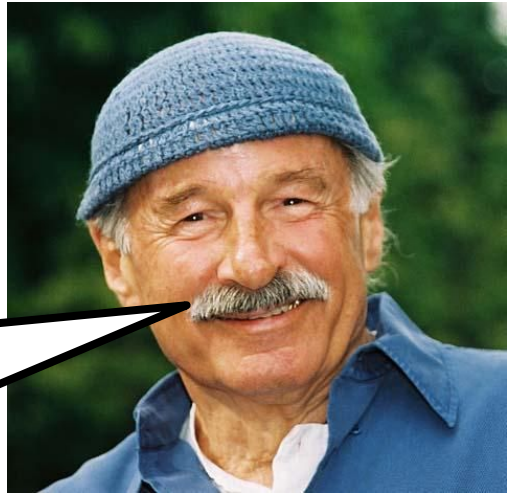
```
{
  "user": {
    "name": "Jane",
    "gender": "female",
    "location": {
      "href":
"http://www.example.org/us
/ny/new_york",
      "text": "New York"
    }
  }
}
```

← This resource is a description of a user named Jane

- Requested by sending GET request for the resource's URL, e.g., via curl:
  `curl http://www.example.org/users/jane/`
- If users need to modify the resource, they GET it, modify it, and PUT it back
- The href to the location resource allows savvy clients to get more information with another simple GET request
- Implication: Clients cannot be too "thin"; need to understand resource formats!

Joe Zawinul

I said, “What’s that?” and he said, “That’s **jazz**.” “How do you write that?” And he spelt it out. Somehow I saw my name in there, and I liked this word.

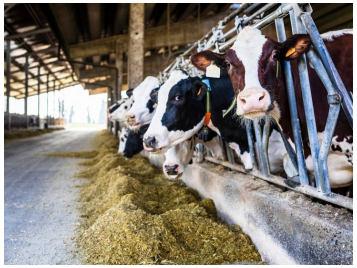


Robert West

I said, “What’s that?” and he said, “That’s **REST**.” “How do you write that?” And he spelt it out. Somehow I saw my name in there, and I liked this word.

[link]

Cooking with data



Part 2:
Data sources

Part 1:
Data models

Part 3:
Data wrangling

Working with raw data sucks

Data comes in all shapes and sizes

– CSV files, PDFs, SQL dumps, .jpg, …

Different files have different formatting

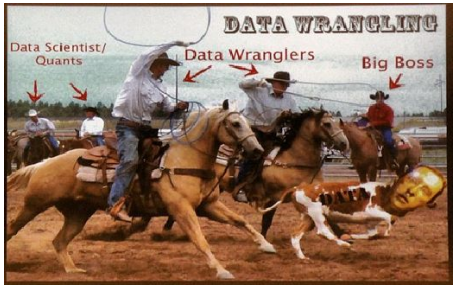
– Empty string or space instead of NULL, extra header rows, character encoding, …

“Dirty” data

– Unwanted anomalies, duplicates

Raw data without thinking: A recipe for disaster!

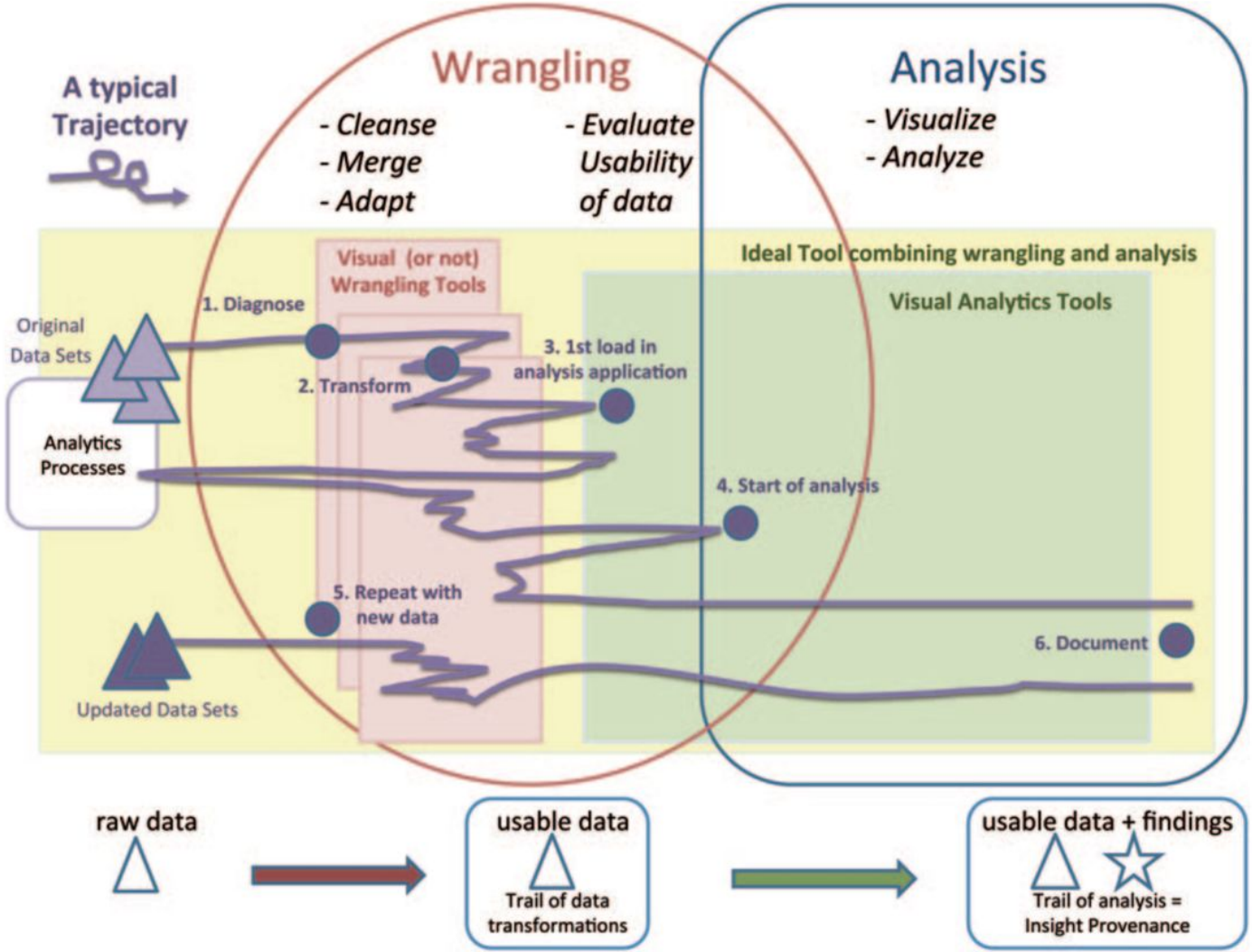
What is data wrangling?



- **Goal:** extract and standardize the raw data
  - Combine multiple data sources
  - Clean data anomalies
- **Strategy:** Combine automation with interactive visualizations to aid in cleaning
- **Outcome:** Better efficiency and scale of data importing

Wrangling takes **between 50% and 80% of your time…**

[Source]

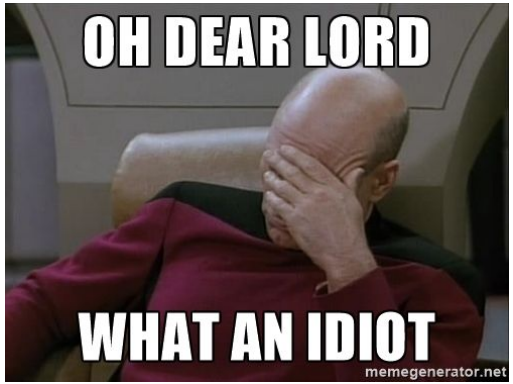


Types of data problems

- Missing data
- Incorrect data
- Inconsistent representations of the same data
- About 75% of data problems require human intervention (e.g., experts, crowdsourcing, etc.)
- Tradeoff between cleaning data vs. over-sanitizing data

link

“Dirty data” horror stories



“Dear Idiot” letter

17,000 men are pregnant

As the crow flies

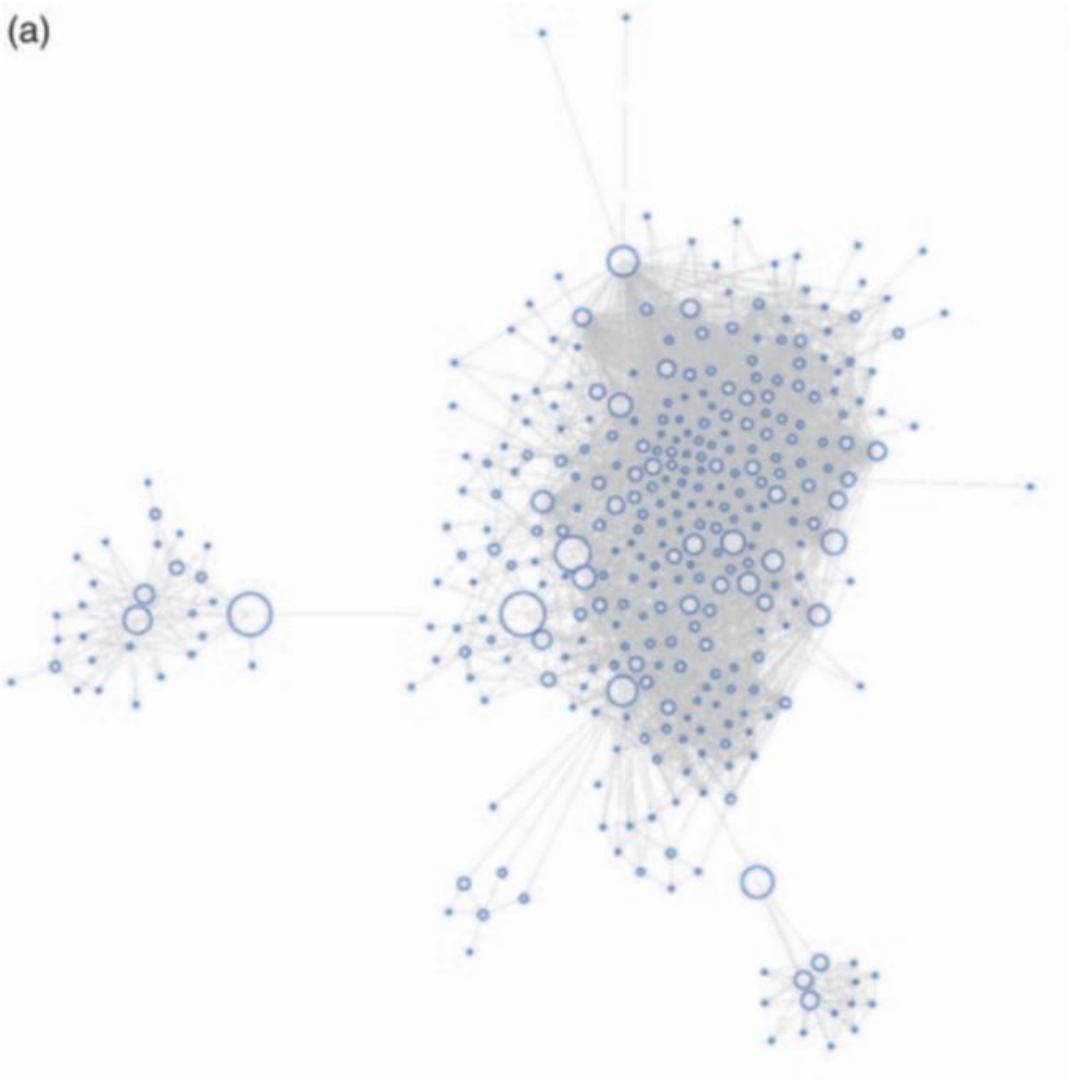
CHF 10,000 compute-cluster bill

[Source]

Diagnosing data problems

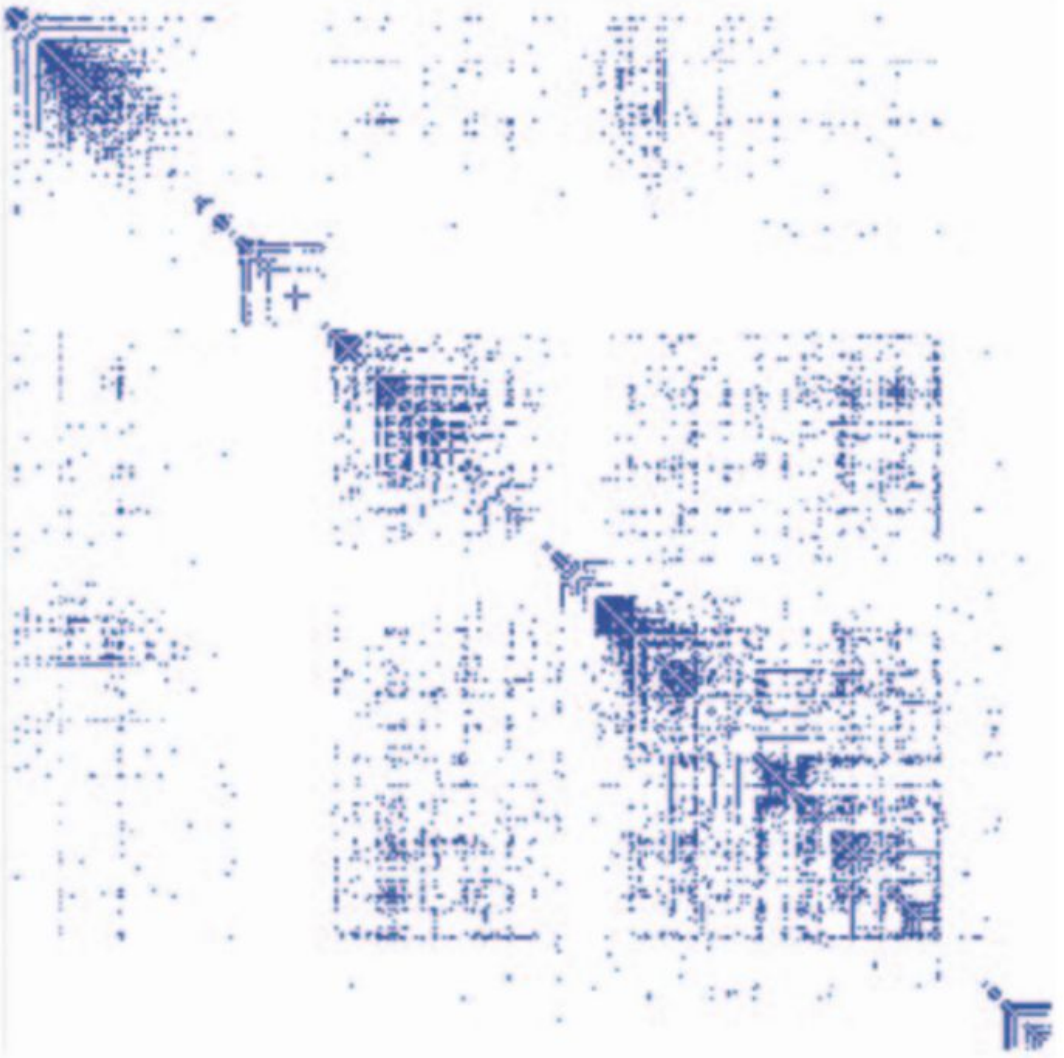
- Visualizations and basic stats can convey issues in “raw” data
- Different representations highlight different types of issues:
  - Outliers often stand out in the right kind of plot
  - Missing data will cause gaps or zero values in the right kind of plot
- Becomes increasingly difficult as data gets larger
  - Sampling to the rescue!

Facebook graph



Matrix view (1)

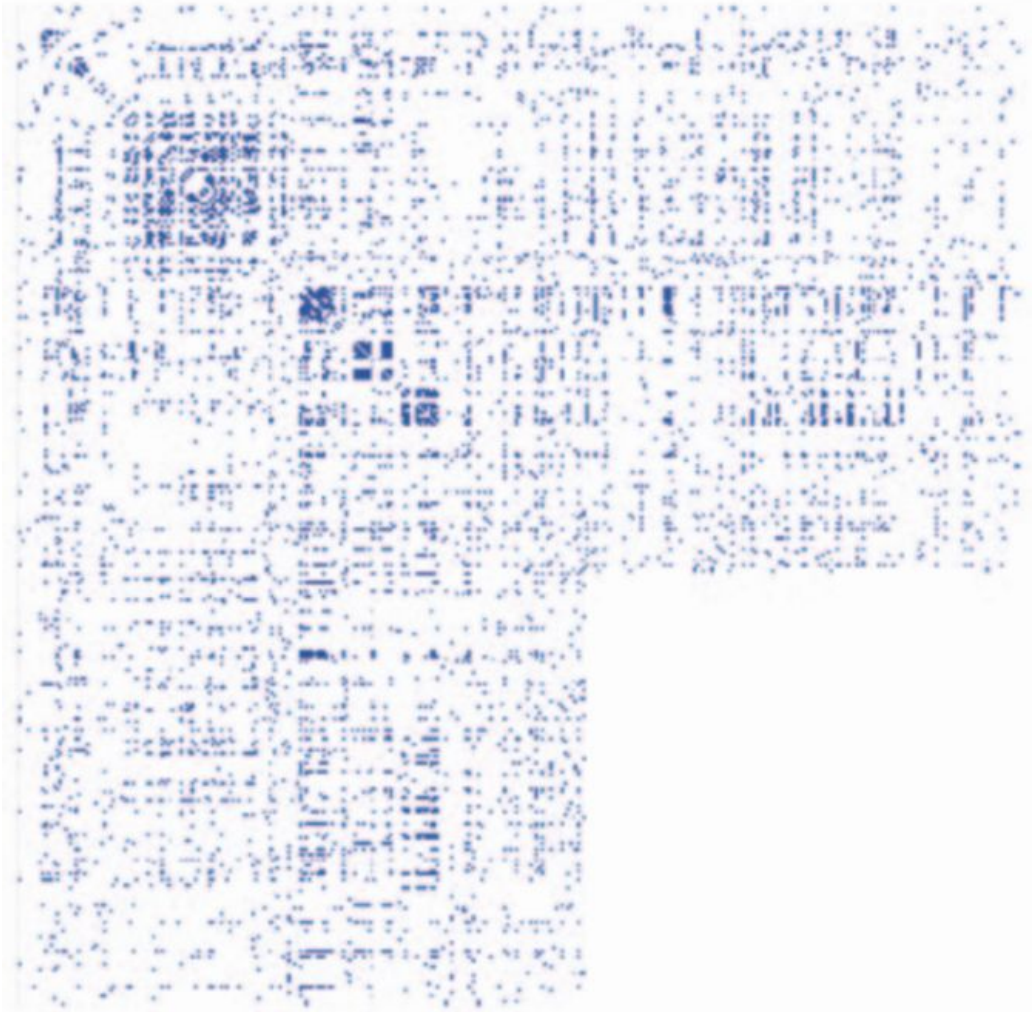
Automatic permutation of rows and columns to highlight patterns of connectivity



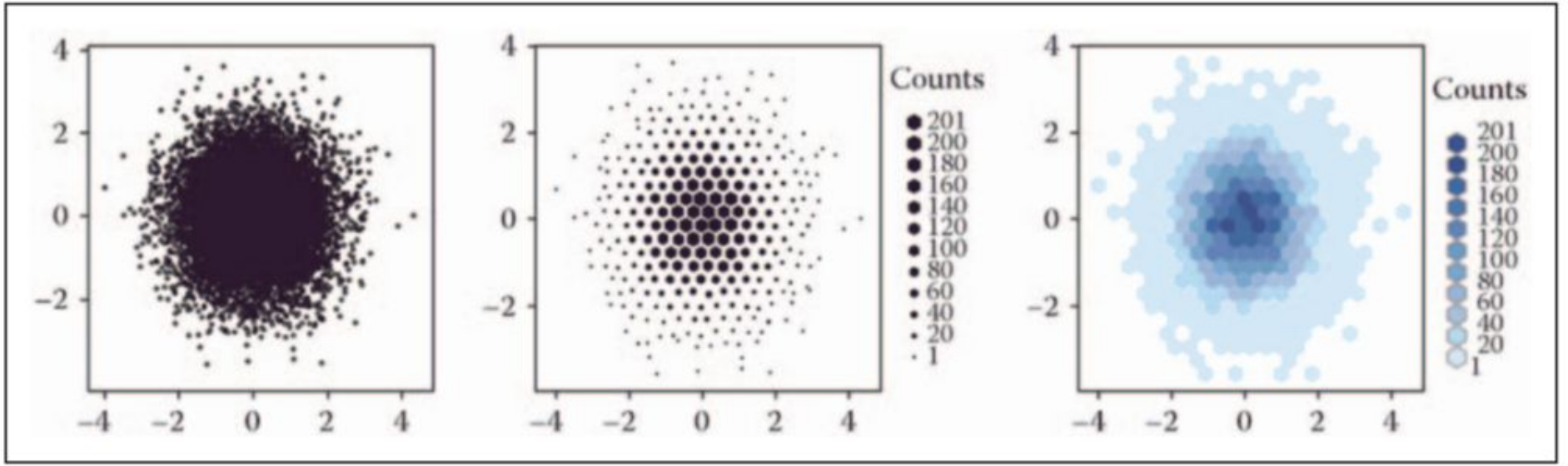
Matrix view (2)

Rows and columns sorted in the order in which data was retrieved via the Facebook API

Can you guess what's going on here?

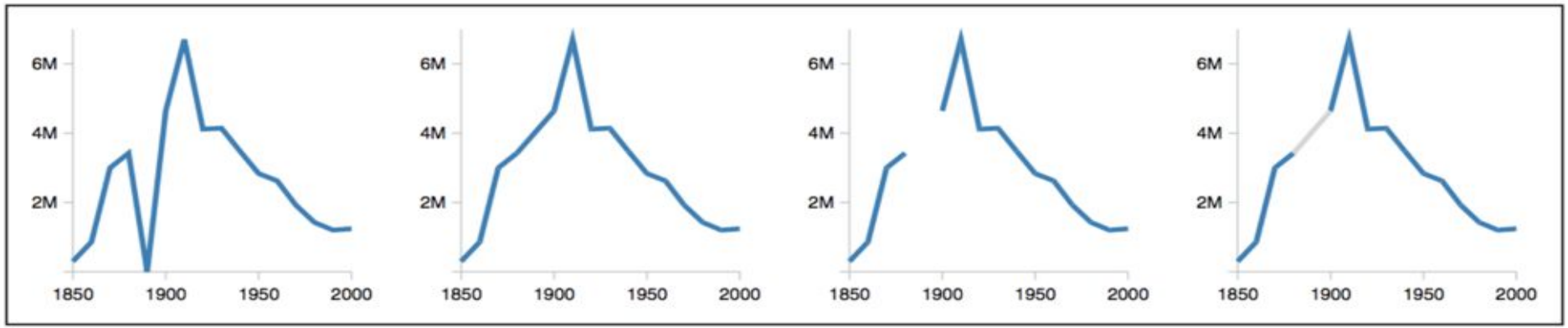


Viz at scale? Careful!



Dealing with missing data

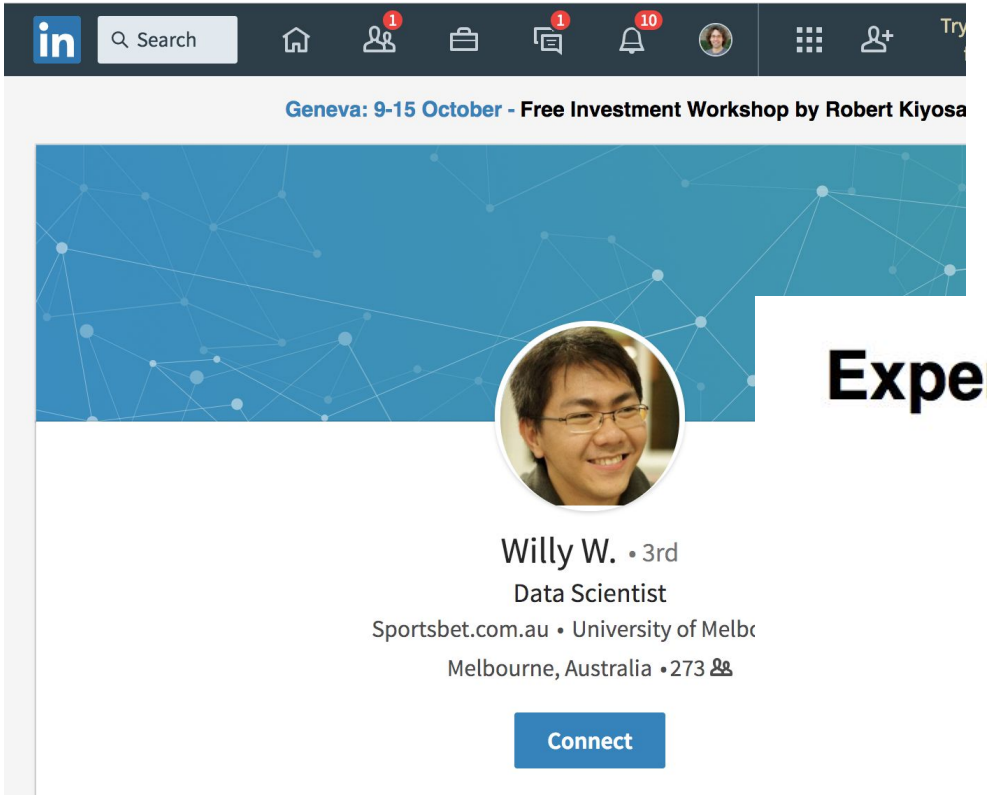
U.S. census counts of people working as ‘‘farm laborers’’; values from 1890 are **missing due to records being burned in a fire**



- Set values to zero?
- Interpolate based on existing data?
- Omit missing data?

Knowledge about domain and data collection should drive your choice!

Inconsistent data: “My name is Willy”



First name	Last name
Willy	NULL
…	…

Experiments on Pattern-based Rel

Willy Yap and Timothy Baldwin
NICTA Victoria Research Laboratory
Department of Computer Science and Software E
University of Melbourne
willy@csse.unimelb.edu.au, tim@csse.unir

Before you start analyzing your data

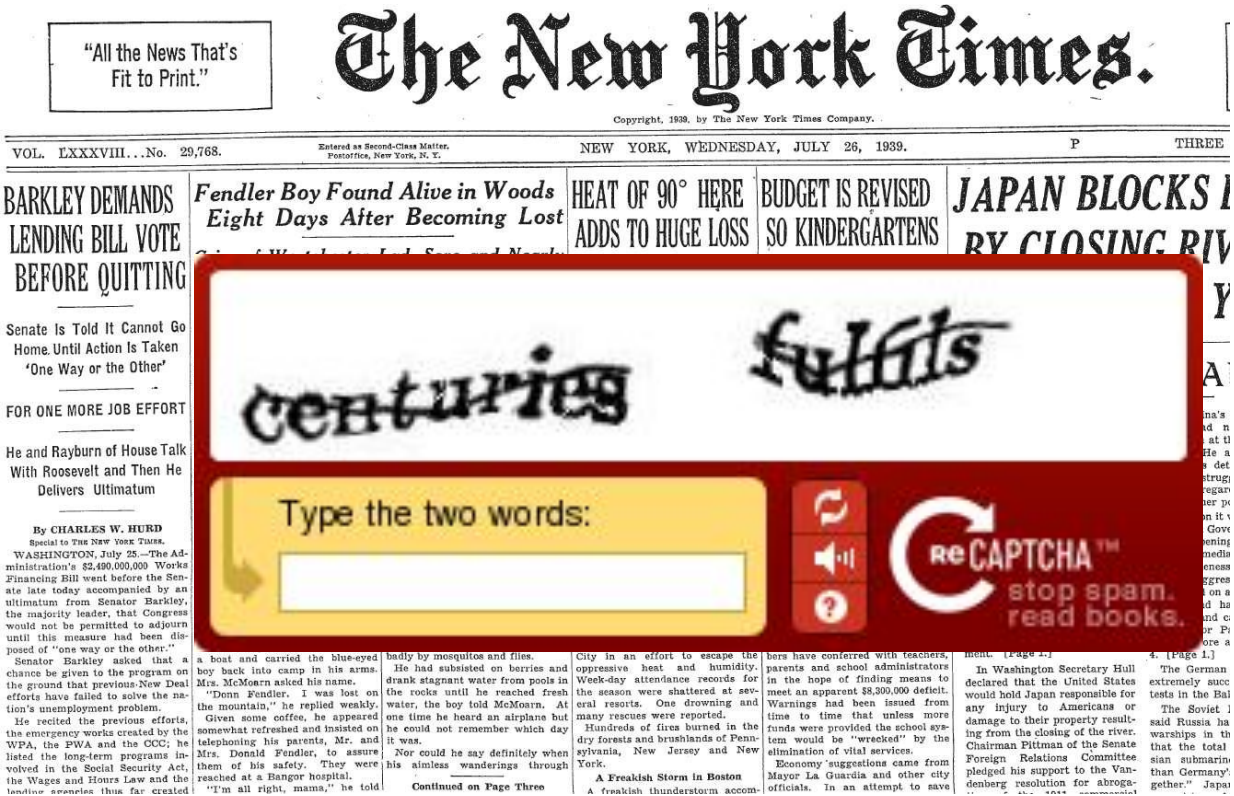
- “Do I have **missing data**?” “If data were missing, how could I know?”
- “Do I have **corrupted data**?” (May arise from measurement errors, processing bugs, etc.)
- **Parse/transform data** into appropriate format for your specific analysis (see “Part 1: Data models”)
- Don’t be surprised if you need to come back to this stage!

Desiderata

It's always ideal if you can put your hands on the **code/documentation about the dataset** you are analyzing (provenance)

It's always ideal if the provided **data format is nicely parseable** (otherwise you need regexes, or maybe even pay humans)

Highly non-parseable data



Entire NY Times archive (since 1851) digitized as of 2015

Example from Bob's research (AD 2013)

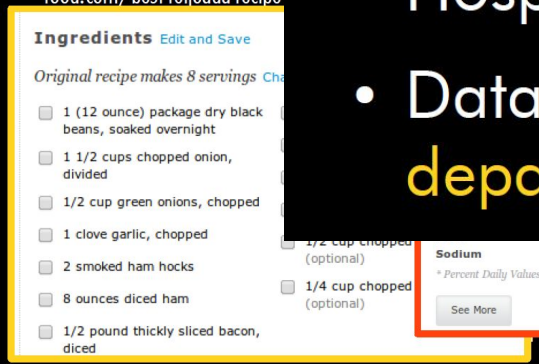
Q: What do

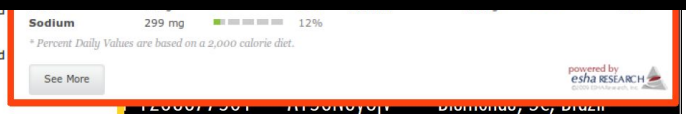
- Find Amazon add-to-cart events heuristically in logs:
  - Referrer: http://www.amazon.com/Forks-Over-Knives-Plant-Based-Health/dp/1615190457
  - URL: http://www.amazon.com/gp/cart/view-upsell.html?...
- Get product info for product id using Amazon API
- Consider all add-to-cart events for category "Diets & Weight Loss"

Our method: I

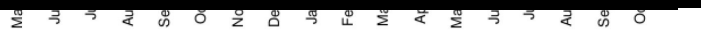
Consenting IE users, 18 mo

URL	Referrer	Tim
yahoo.com?q=the+onion	yahoo.com	128
theonion.com	yahoo.com?q=the+onion	128
theonion.com/Area-Man-Sad		
bing.com		
bing.com?q=feijoada+recipe		
allrecipes.com/tasty-feijoada		
food.com/best-feijoada-recipe		





- Collaborated with clinician at Washington Hospital Center, Washington, D.C.
- Data: All CHF admissions to emergency department for time period of our browsing logs



[Paper with results and plots]

Feedback

Give us feedback on this lecture here:
https://go.epfl.ch/ada2022-lec2-feedback

Feedback form available for each lecture and lab session

- What did you (not) like about this lecture?
- What was (not) well explained?
- On what would you like more (fewer) details?
- Is it nicer to follow the lecture online or offline?
- …