http://poloclub.gatech.edu/cse6242

CSE6242: Data & Visual Analytics

Data Integration

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Founder of Filio, a visual asset management platform

Partly based on materials by

Professors Guy Lebanon, Jeffrey Heer, John Stasko, Christos Faloutsos

Collection

Cleaning

Integration

Analysis

Visualization

Presentation

Dissemination

What is Data Integration?

Combining data from multiple sources to provide the user with a unified view.

Why is it Important?

Think about the apps, websites, and services that you use every day.

Businesses **derive value** through data integration.

atlanta

Sign In

All Maps News Images Videos More Settings Tools

About 467,000,000 results (0.64 seconds)

Atlanta, GA : Home
https://www.atlantaga.gov/
It is a great time to be in the City of **Atlanta**! Whether you're a native, first time visitor, business traveler who makes regular stops here, or one of the thousands of ...

Atlanta - Wikipedia
https://en.wikipedia.org/wiki/Atlanta
Atlanta is the capital of and the most populous city in the U.S. state of Georgia, with an estimated 2016 population of 472,522. **Atlanta** is the cultural and ...
Atlanta (disambiguation) · Hartsfield–Jackson Atlanta · Demographics of Atlanta

Top stories

Crash kills brothers returning to Georgia Southern after Thanksgiving br…

AJC.com

18 hours ago

Postal worker shot in the head, killed outside Atlanta

Fox News

20 hours ago

New FOX 5 poll: Virtual dead heat in Atlanta mayor's race

FOX 5 Atlanta

9 hours ago

More for atlanta

Things to do in Atlanta

Atlanta

City in Georgia

Atlanta is the capital of the U.S. state of Georgia. It played an important part in both the Civil War and the 1960s Civil Rights Movement. Atlanta History Center chronicles the city's past, and the Martin Luther King Jr. National Historic Site is dedicated to the African-American leader's life and times. Downtown, Centennial Olympic Park, built for the 1996 Olympics, encompasses the massive Georgia Aquarium.

Weather: 51°F (11°C), Wind NE at 3 mph (5 km/h), 96% Humidity

Local time: Wednesday 6:14 AM

Population: 472,522 (2016)

Area code: 404

Plan a trip

Atlanta travel guide

3-star hotel averaging $128, 5-star averaging $366

Upcoming Events

Colleges and Universities: Emory University, MORE

Did you know: Atlanta has the world's fourth-busiest city airport system by passenger traffic (101,491,106 total passengers). wikipedia.org

People also search for

View 15+ more

Apple Siri

Getting Answers

"Do I need an umbrella today?"

"How is the Nikkei doing?"

"When is daylight saving time?"

"Was that an earthquake?"

"What's the latest in San Francisco?"

See what people are saying on social media about a place or event.

KAYAK Hotels Flights Cars Packages Rentals Cruises More My Account

Search hundreds of travel sites at once.

HOTELS FLIGHTS CARS PACKAGES

ROUND-TRIP ONE-WAY MULTI-CITY EXPLORE

Atlanta (ATL) San Francisco (SFO Depart – Return 1 adult, Economy

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Recommended for you

More Examples?

- **Social media** (data from users, businesses)
  - Facebook: your posts, advertisements, review
- **Search engine:** Google, Bing, Yahoo, etc.
- **Smart assistants:** Siri, Cortana, Alexa, Google
- **Price comparison**: Kayak
- Uber, Lyft: drivers, traffic data, customers
- google maps: users, restaurants, traffic….

How to do data integration?

“Low” Effort Approaches

1. **Use database’s “Join”!** (e.g., SQLite)

When does this approach work?
(Or, when does it NOT work?)

id	name
111	Smith
222	Johnson
333	Lee

id	salary
111	$40k
222	$60k
333	$50k

id	name	salary
111	Smith	$40k
222	Johnson	$60k
333	Lee	$50k

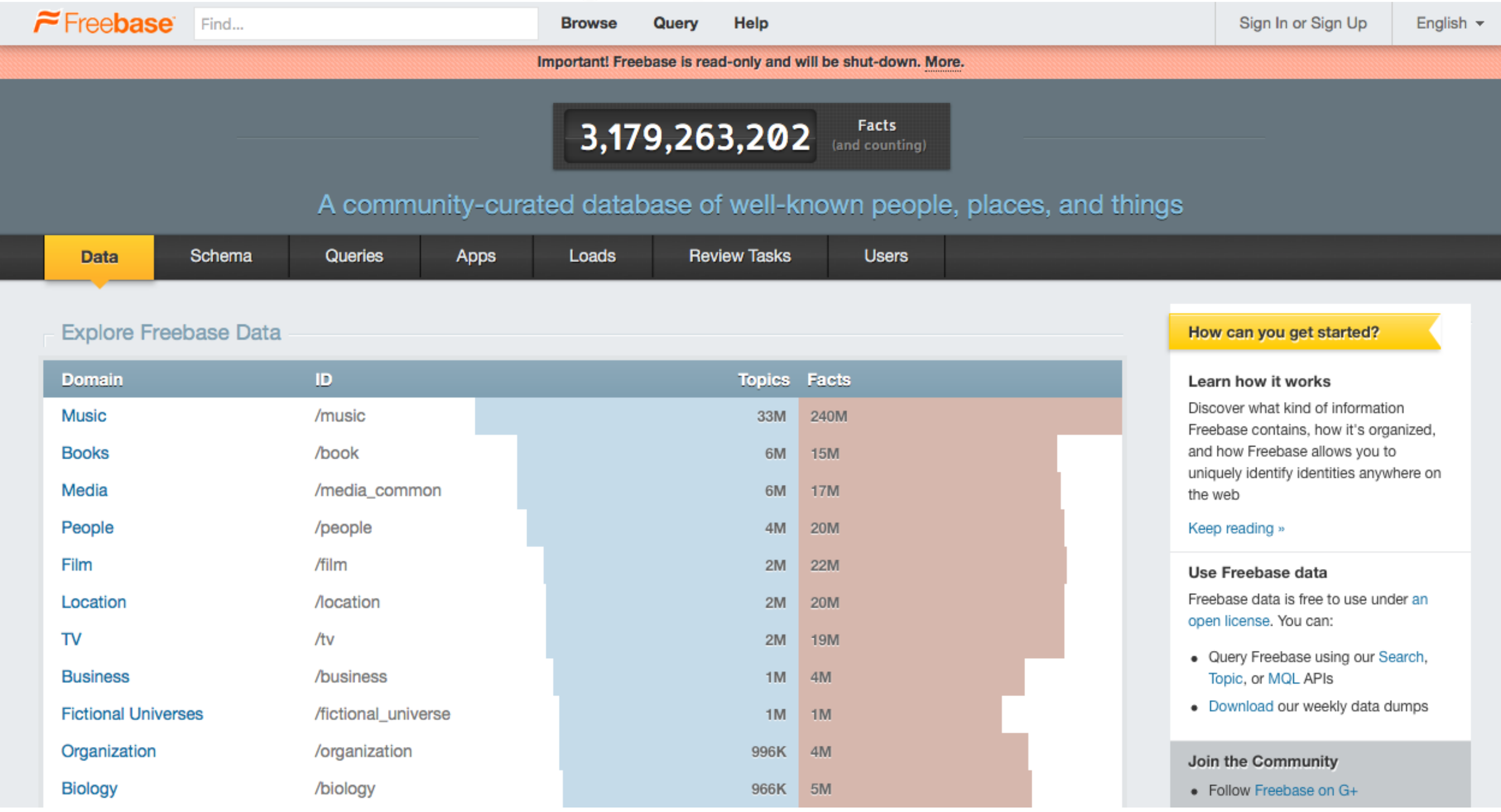
2. **Open Refine**

http://openrefine.org (Video #3 **“Reconcile and Match Data”**)

IDs are really important, and can simplify data integration!

But who creates the IDs?

Crowd-sourcing Approaches: Freebase



Freebase intro video: https://youtu.be/TJfrNo3Z-DU

Learn more about Freebase at https://en.wikipedia.org/wiki/Freebase

Freebase

(a graph of entities)

"…a large collaborative knowledge base consisting of metadata composed mainly by its **community members**…"

Wikipedia.

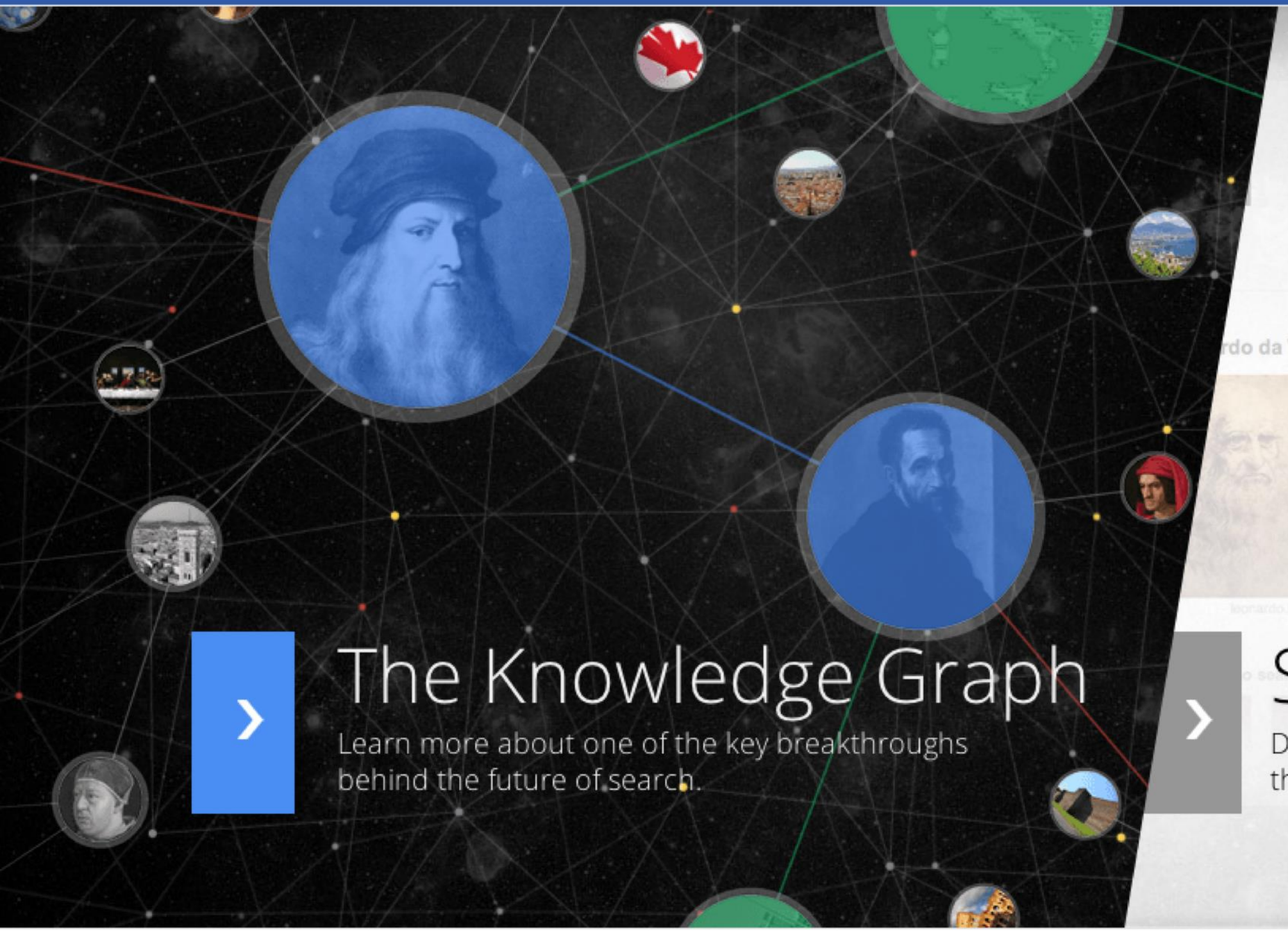
So what?

What can you do with the Freebase knowledge graph?

Hint: Google acquired it in 2010.

Google | Inside Search

Home Tips & Tricks **Features** Search Stories Playground Blog Help



Google Knowledge Graph video: https://youtu.be/mmQl6VGvX-c

Freebase replaced by **Google Knowledge Graph API**

Example:

What does Google know about Taylor Swift?

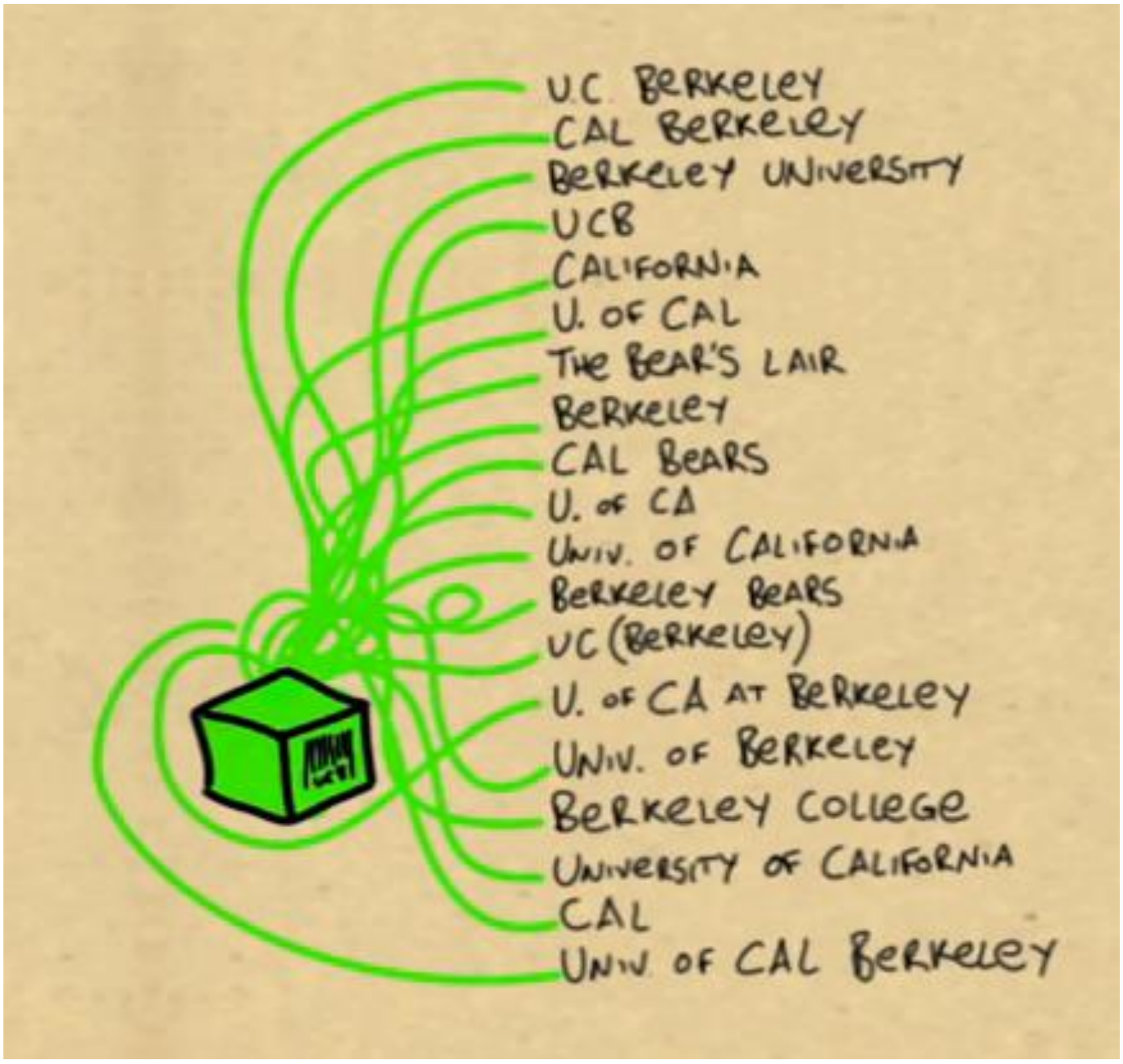
https://developers.google.com/knowledge-graph/

What does Google know about Taylor Swift?

https://developers.google.com/knowledge-graph/


```
"@type": "ItemList",
"itemListElement": [
  {
    "@type": "EntitySearchResult",
    "result": {
      "@id": "kg:/m/0dl567",
      "name": "Taylor Swift",
      "@type": [
        "Thing",
        "Person"
      ],
      "description": "Singer-songwriter",
      "image": {
        "contentUrl": "https://t1.gstatic.com/images?q=tbn:ANd9GcQmVDAhjhWnN2OWys2ZMO3PGAhu
        "url": "https://en.wikipedia.org/wiki/Taylor_Swift",
        "license": "http://creativecommons.org/licenses/by-sa/2.0
      },
      "detailedDescription": {
        "articleBody": "Taylor Alison Swift is an American singer-songwriter and actress. R
        "url": "http://en.wikipedia.org/wiki/Taylor_Swift",
        "license": "https://en.wikipedia.org/wiki/Wikipedia:Text_of_Creative_Commons_Attrib
      },
      "url": "http://taylorswift.com/"
```

What if we don't have the luxury of having IDs ?



(Screenshot from FreeBase video)

A common problem in academia:

Polo Chau
Duen Horng Chau
Duen Chau
D. Chau

Then you need to do…

Entity Resolution

(A hard problem in data integration)

Why is **entity resolution** so difficult?

Let’s understand it through shopping for an iPhone on Apple, Amazon and eBay

If you're part of the iPhone Upgrade Program, you may be eligible for a new iPhone. Find out now ›

Model Carrier Finish Capacity

Buy your new iPhone X.

Get free next-business-day delivery on any in-stock iPhone ordered by 5:00 p.m.*

iPhone X

5.8-inch display*

Select

From $49.91/mo. with the iPhone Upgrade Program.[1]
Or pay in full from $999.

1-60 of 514 results for **Cell Phones & Accessories : Cell Phones : "iPhone x"**

Sort by Relevance

Show results for

- Any Category
- Cell Phones & Accessories
  - **Cell Phones**
    - Unlocked Cell Phones
    - Carrier Cell Phones

Refine by

Delivery Day
- Get It by Tomorrow

Amazon Prime
- prime

Eligible for Free Shipping
- Free Shipping by Amazon

Brand
- Apple
- ASA
- GooPhone
- iHarbort
- EcoSale777
- CRAFIC
- AGRIGLE
- TechCode
- without brand

See more

Cell Phone Display Size
- 3.9 Inches & Under
- 4.0 to 4.4 Inches
- 4.5 to 4.9 Inches
- 5.0 to 5.4 Inches
- 5.5 Inches & Over

Phone Color

Cell Phone Internal Storage Memory
- Under 4 GB
- 4 GB
- 8 GB
- 16 GB
- 32 GB
- 64 GB
- 128 GB
- 256 GB & Above

Cell Phone Features

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iPhone X Case - Zizo [Static Series] Shoc...
prime 4.5 stars 110

iPhone X Case - Zizo [ION Series] with F...
prime 4.0 stars 123

iPhone X Case - Zizo [Bolt Series] with S...
prime 4.5 stars 677

Ad feedback

Showing most relevant results. See all results for iPhone x.

Sponsored
RETINA iPhone Wide Angle Lens 0.6 x | 60% Wider Picture With Every Snap | Bundle With 10x Macro Lens Pro | Clip-On Cell...
$34.99 prime
4.5 stars 7

Sponsored
SPEATE iPhone Charger Cable Nylon Braided Lightning to USB Cord with 3PACK 3FT 6FT 10FT Fast Syncing and Charging for...
$11.99 prime
4.5 stars 113

Sponsored
Lightning Cable, NiocTech Nylon Braided USB A to Lightning Compatible Cable for iPhone X / 8 / 8 Plus / 7 / 7 Plus / 6 / 6...
$9.99 prime
4.5 stars 30

Apple iPhone X, GSM Unlocked 5.8", 256 GB - Space Gray
More Choices from $1,260.00
4.5 stars 69
Price may vary by color

Apple iPhone X, Fully Unlocked 5.8", 64 GB - Silver
$1,148.99
4.0 stars 36
Price may vary by color

Apple iPhone X 256 GB T-Mobile - Space Gray, Locked to T-Mobile
$1,315.00

New Apple iPhone X, GSM Unlocked 5.8", 256 GB - Silver
More Choices from $1,150.00

24K Gold Plated iPhone X 256 GB Silver - Unlocked Custom
More Choices from $2,199.00

Apple iPhone X AT&T 64GB (Space Gray) Locked to AT&T
$1,170.00 ~~$1,350.00~~

iPhone X Case, Crystal Clear Shock Absorption Technology Bumper Transparent TPU+Acrylic Cover vase for...
$8.99 prime
4.5 stars 3

Categories

All

‹ Cell Phones & Accessories

Cell Phone Accessories

Cell Phones & Smartphones

Cell Phone & Smartphone Parts

Other Cell Phones & Accs

More

Computers/Tablets & Networking

Consumer Electronics

Clothing, Shoes & Accessories

Business & Industrial

Sporting Goods

Show more

Features see all

- 3G Data Capable (134)
- 4G Data Capable (151)
- 4K Video Recording (140)
- Accelerometer (108)
- Bluetooth Enabled (154)
- Dual Rear Cameras (87)
- Fingerprint Sensor (69)
- Wireless Charging (45)

Network see all

- AT&T (263)
- Sprint (105)
- T-Mobile (79)
- Verizon (118)
- Unlocked (554)

Color see all

- Black (85)
- Clear (71)
- Gold (33)
- Gray (696)
- Silver (411)

Storage Capacity see all

- 256GB (627)
- 64GB (553)

Processor see all

- Dual Core (92)
- Hexa Core (986)

Model Number see all

Find deals and best selling products for **Apple iPhone X Cell Phones & Smartphones** Shop Now →

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Sort: Best Match View: Group Similar Listings

1,475 results for **iphone x** Save this search

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Brand New - Sealed Apple iPhone X 256GB SILVER A1901

Apple iPhone X - 256GB - Space Gray AT&T A1901 (GSM)

BRAND NEW, Apple iPhone X MQCL2LL/A A1865 64GB Silver

Browse related

Cables & Adapters for iPhone X

Tool Kits for iPhone X

D-Dupe

Interactive Data Deduplication and Integration

TVCG 2008

University of Maryland
Bilgic, Licamele, Getoor, Kang, Shneiderman

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4035746
https://linqspub.soe.ucsc.edu/basilic/web/Publications/2006/bilgic:vast06/

D-Dupe 2.0

File Edit View Window Help

Back Forward

Search Potential Duplicate Pairs by Similarity Metric

Potential Duplicate Pairs | Similarity Metric

Similarity	Left Node	Right Node
0.982	Elizabeth Churchill	Elizabeth F. Churchill
0.981	Kristian Simsarian	Kristian T. Simsarian
0.981	Gregg Vanderheiden	Gregg C. Vanderheiden
0.981	Christine Neuwirth	Christine M. Neuwirth
0.981	George W. Fitzmaurice	George Fitzmaurice
0.981	Catherine R. Marshall	Catherine C. Marshall
0.980	Pamela K. Schraedley	Pamela Schraedley
0.980	Katherine M. Everitt	Katherine Everitt
0.980	Mija Van Der Wege	Mija M. Van Der Wege
0.980	Elizabeth Veinott	Elizabeth S. Veinott
0.979	Timothy Bickmore	Timothy W. Bickmore

Potential duplicate viewer

Search Algorithm: Blocking Algorithm - Sample Clustering By Nam

Search Potential Duplicates: Both Within and Across Data Source I

Number of Potential Duplicate Pairs (1 ~ 300): 200

Search Potential Duplicate Pairs

Search Nodes by Keywords

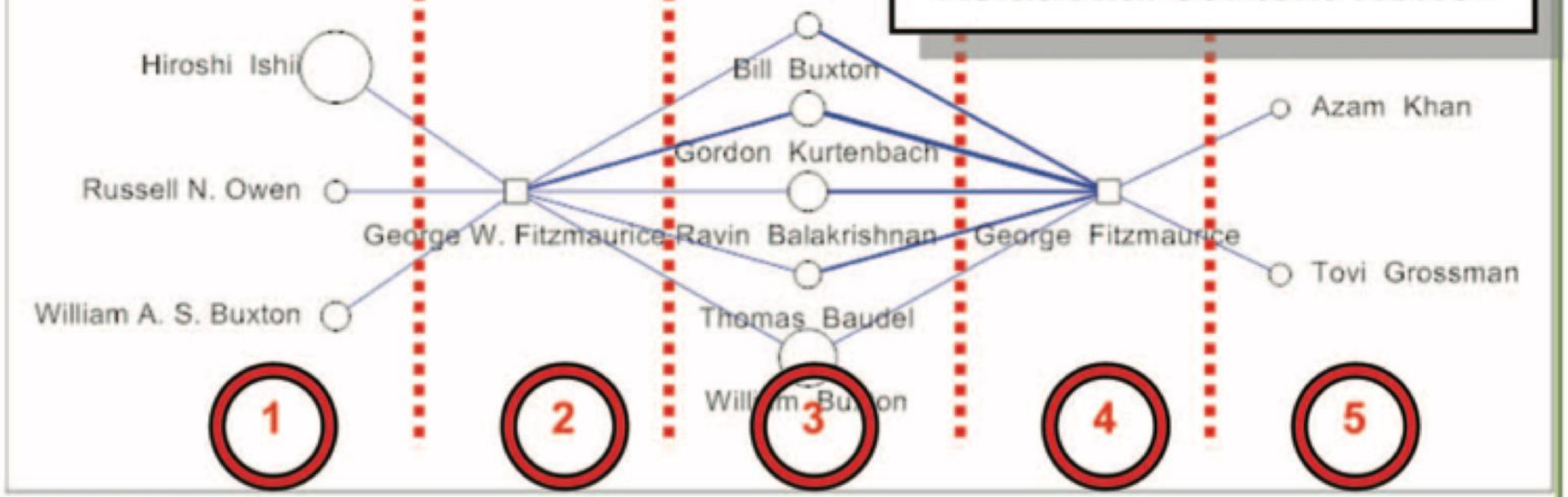
Search

person_id	full_name	last_name	first_name	mid

Search Potential Duplicates of Selected Node

Name Ascending | Number of Edge E | Show All Edges

Relational context viewer



Potential Duplicates Viewer

person_id	full_name	last_name	first_name	middle_name	suffix	affiliation
P95459	George W. Fitzmaurice	Fitzmaurice	George	W.		
P95460	George Fitzmaurice	Fitzmaurice	George			Alias/wavefront, Toronto, Ontario, Canada and University

Merge Duplicates | Mark Distinct

Node Detail Viewer (10 items)

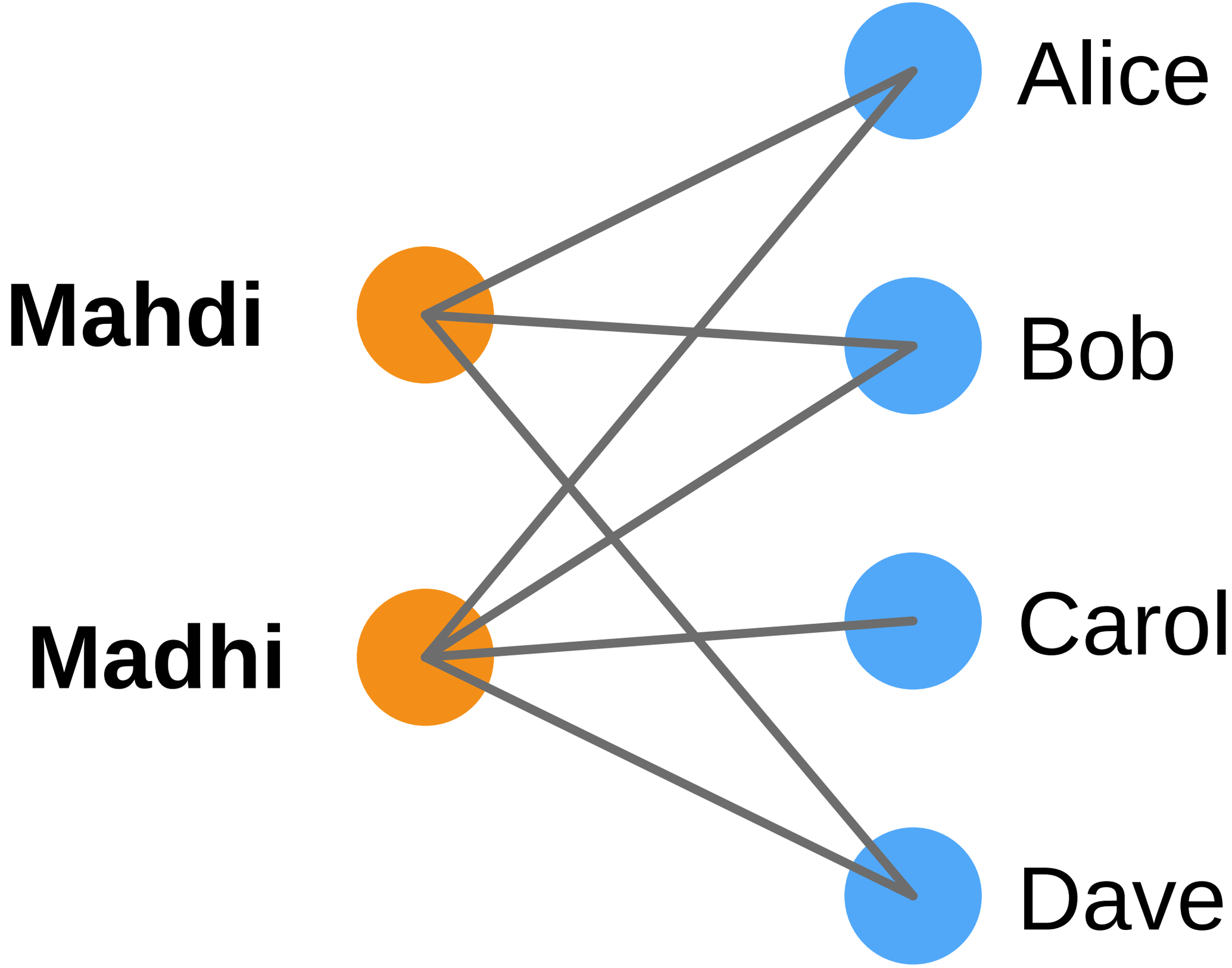
person_id	full_name	last_name	first_name	mid
P110925	Hiroshi Ishii	Ishii	Hiroshi	
P298693	William A. S. Buxton	Buxton	William	A. S
P250512	Russell N. Owen	Owen	Russell	N.
P284951	Tovi Grossman	Grossman	Tovi	
P23365	Azam Khan	Khan	Azam	

Edge Deta

Data detail viewer

article	
223964	Bricks
303047	The Hotbox
503398	Creating principal 3D curves with digital tape drawing
303033	An exploration into supporting artwork orientation in the user i
258578	An emoirical evaluation of orasoable user interfaces

Finding possible duplicates completed!


Mahdi
Madhi
Alice
Bob
Carol
Dave

Core components: **Similarity functions**

Determine how two entities are similar.

D-Dupe's approach:

Attribute similarity + **relational similarity**

$$sim(e_i, e_j) = (1 - \alpha) \times sim_A(e_i, e_j) + \alpha \times sim_R(e_i, e_j),$$
$$0 \leq \alpha \leq 1,$$

Similarity score for a pair of entities

Attribute similarity (a weighted sum)

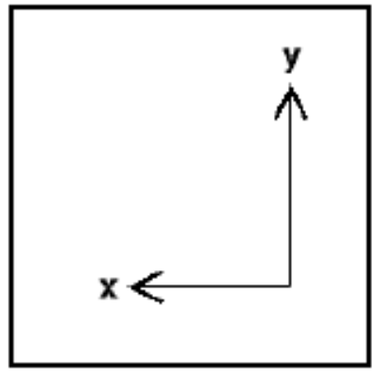
$$sim_A(e_i, e_j) = \sum_{k=1}^{n} w_k \times sim_fun_k(e_i \cdot a_k, e_j \cdot a_k),$$

$$-1 \leq w_k \leq 1 \quad \text{and} \quad \sum_{k=1}^{n} |w_k| = 1,$$

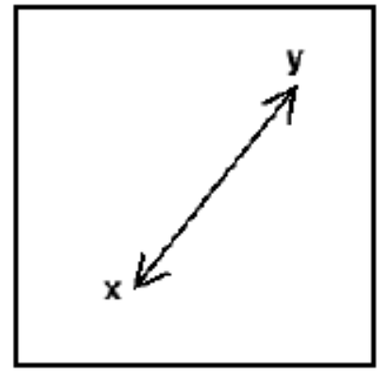
Numerous **similarity functions**

Excellent read: http://infolab.stanford.edu/~ullman/mmds/ch3a.pdf

- Euclidean distance
  Euclidean norm / L2 norm
- TaxiCab/Manhattan distance



Manhattan



Euclidean

- Jaccard Similarity (e.g., used with w-shingles)
  e.g., overlap of nodes' #neighbors

$$Jaccard\ similarity \text{ of sets } S \text{ and } T \text{ is } |S \cap T|/|S \cup T|$$

- String edit distance
  e.g., "Mahdi" vs "Madhi"

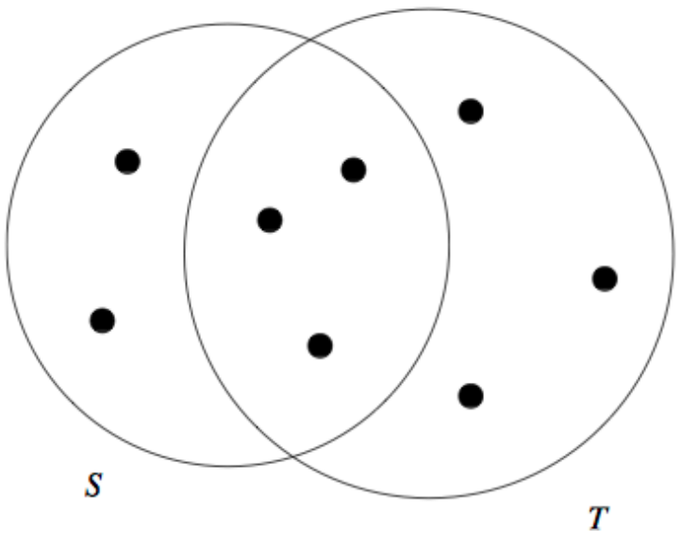


Figure 3.1: Two sets with Jaccard similarity 3/8

Distance and Similarity Measures

Different measures of distance or similarity are convenient for different types of analysis. The Wolfram Language provides built-in functions for many standard distance measures, as well as the capability to give a symbolic definition for an arbitrary measure.

Reference

Numerical Data

EuclideanDistance ▪ **SquaredEuclideanDistance** ▪ **NormalizedSquaredEuclideanDistance** ▪ **ManhattanDistance** ▪ **ChessboardDistance** ▪ **BrayCurtisDistance** ▪ **CanberraDistance** ▪ **CosineDistance** ▪ **CorrelationDistance** ▪ **BinaryDistance** ▪ **TimeWarpingDistance**

Boolean Data

HammingDistance ▪ **JaccardDissimilarity** ▪ **MatchingDissimilarity** ▪ **DiceDissimilarity** ▪ **RogersTanimotoDissimilarity** ▪ **RussellRaoDissimilarity** ▪ **SokalSneathDissimilarity** ▪ **YuleDissimilarity**

String Data

EditDistance ▪ **DamerauLevenshteinDistance** ▪ **HammingDistance** ▪ **SmithWatermanSimilarity** ▪ **NeedlemanWunschSimilarity**

Images & Colors

ImageDistance ▪ **ColorDistance**

https://reference.wolfram.com/language/guide/DistanceAndSimilarity.html

Geospatial & Temporal Data

GeoDistance ▪ **DateDifference**

Excellent Tutorial on Entity Resolution

http://www.umiacs.umd.edu/~getoor/Tutorials/ER_KDD2013.pdf

by Lise Getoor and Ashwin Machanavajjhala