Advanced Data Management (CSCI 640/490)

Introduction

Dr. David Koop

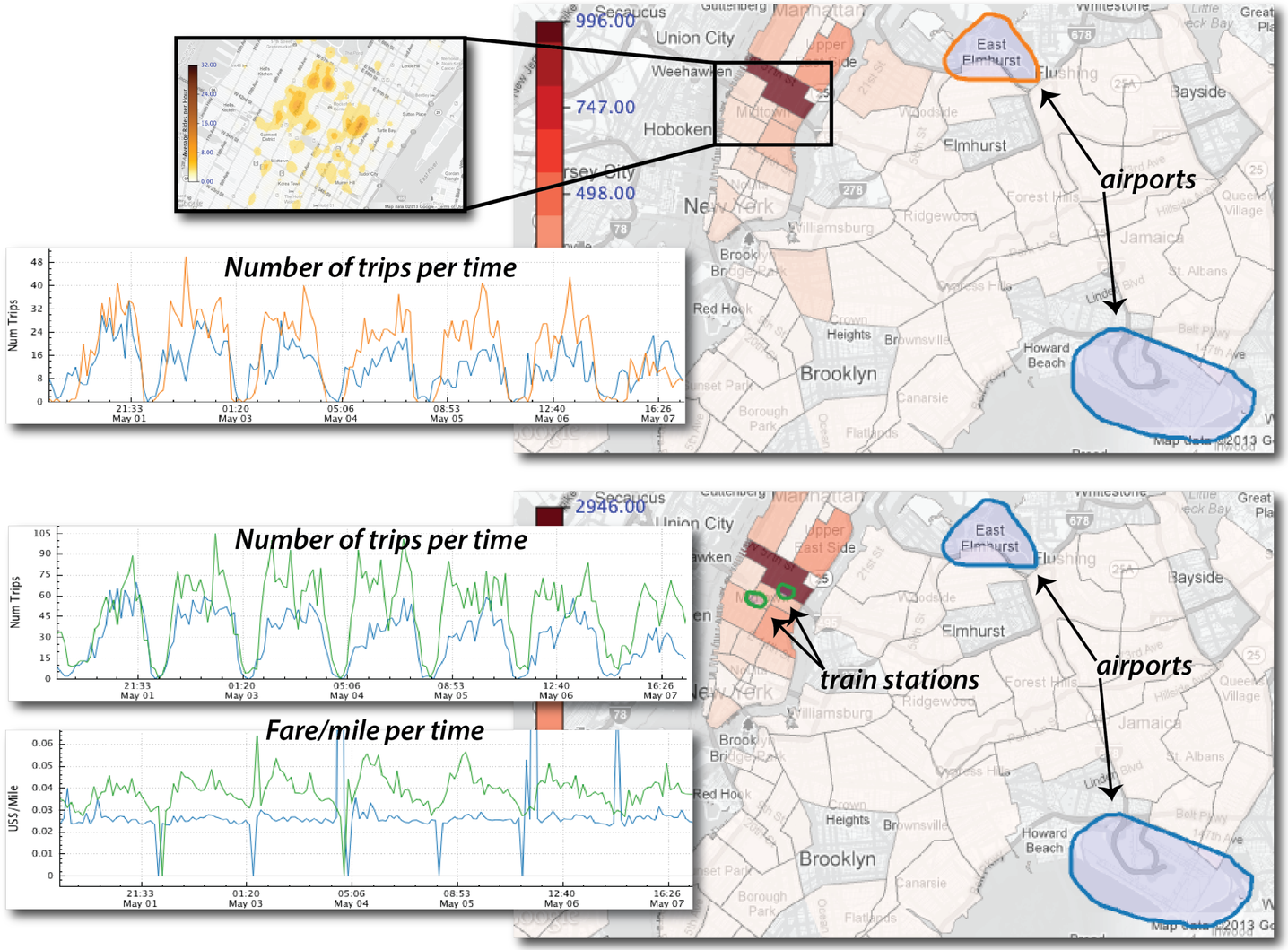
NYC Taxi Data

[Analyzing 1.1 Billion NYC Taxi and Uber Trips, with a Vengeance, T. W. Schneider]

NYC Taxi Data: Day analysis

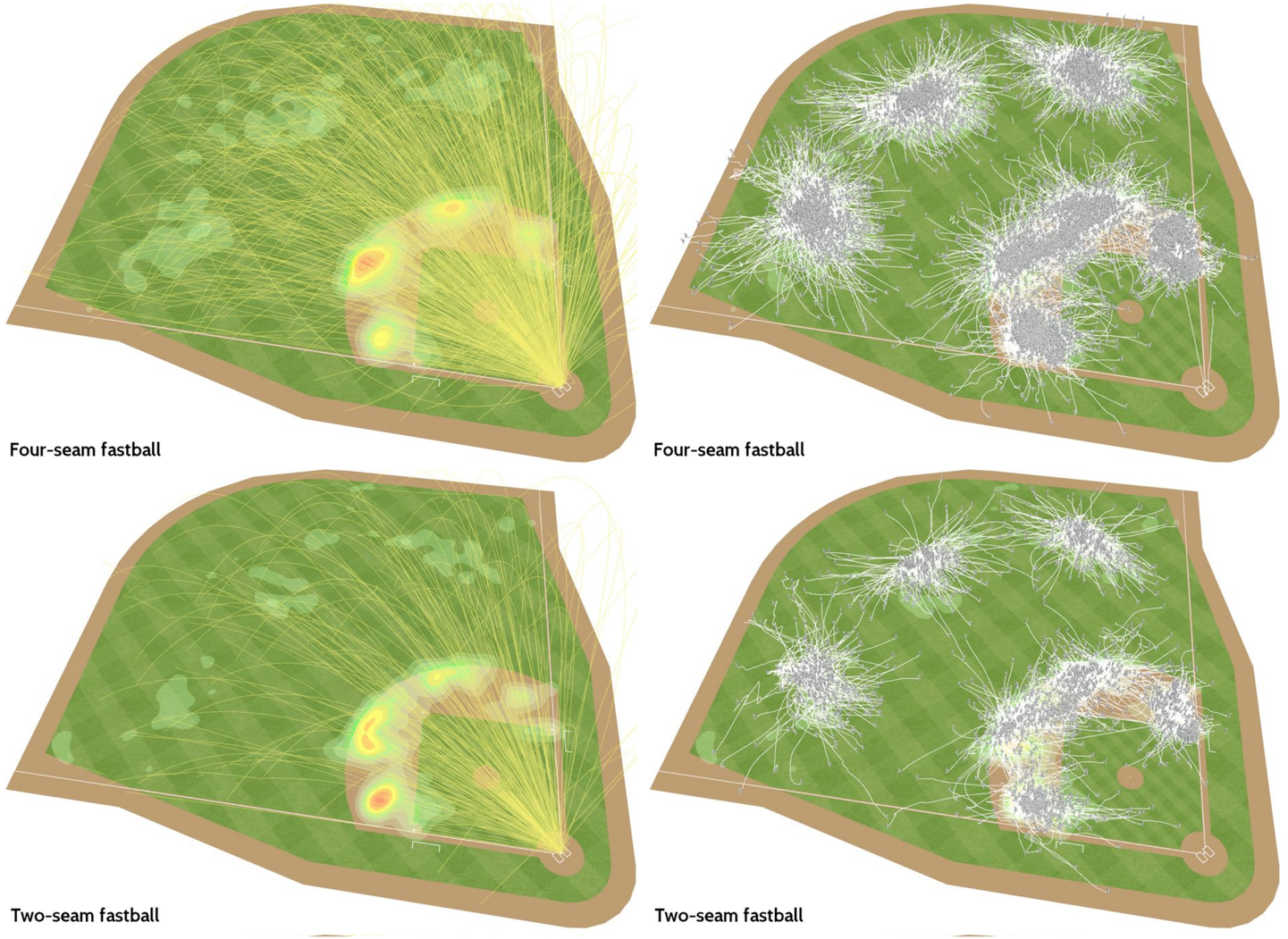
[Ferreira et al., 2013]

NYC Taxi Data: Region analysis



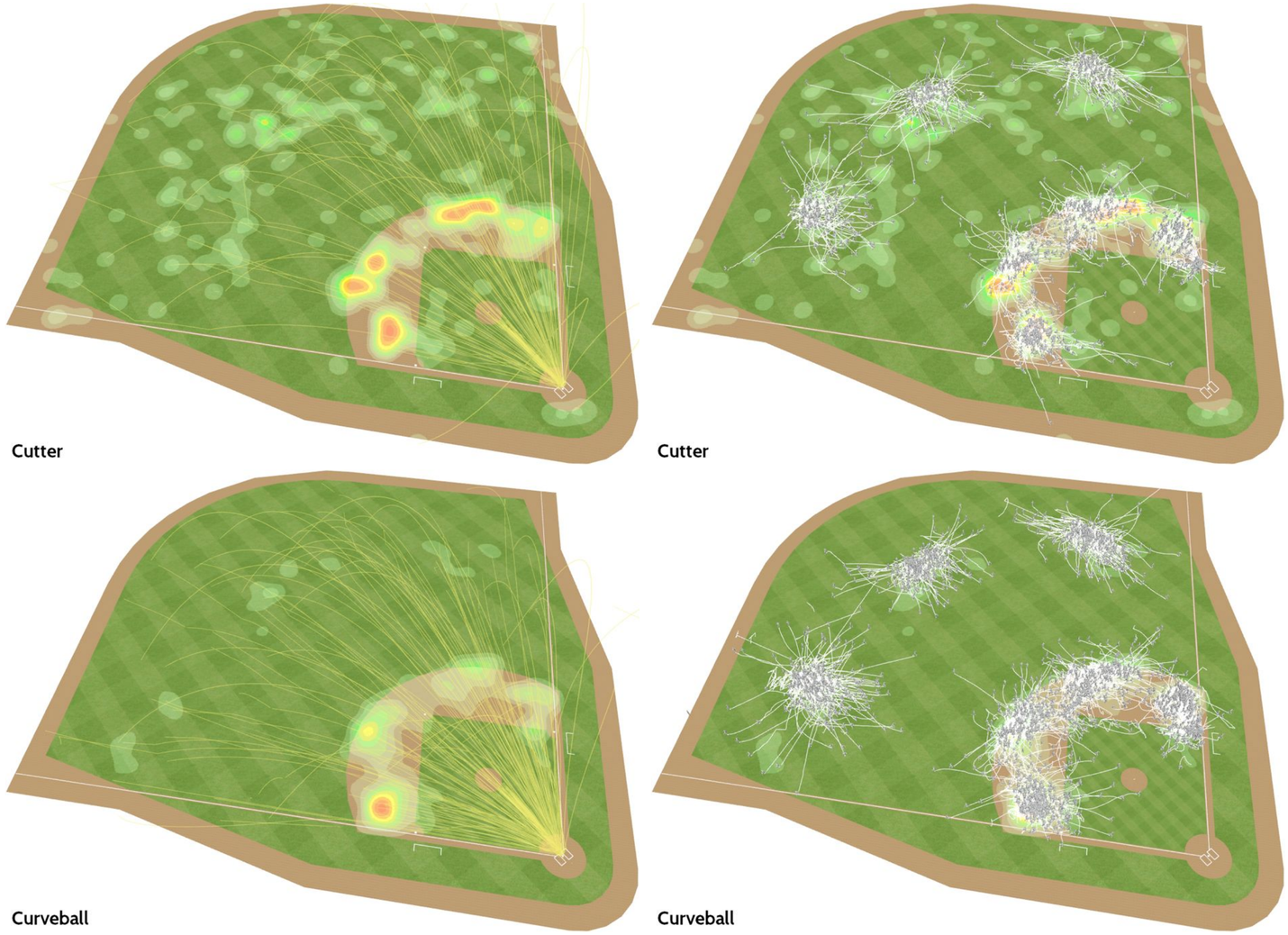
[Ferreira et al., 2013]

Baseball Data



[Deitrich et al., 2014]

Baseball Data



[Deitrich et al., 2014]

Real-time Analysis

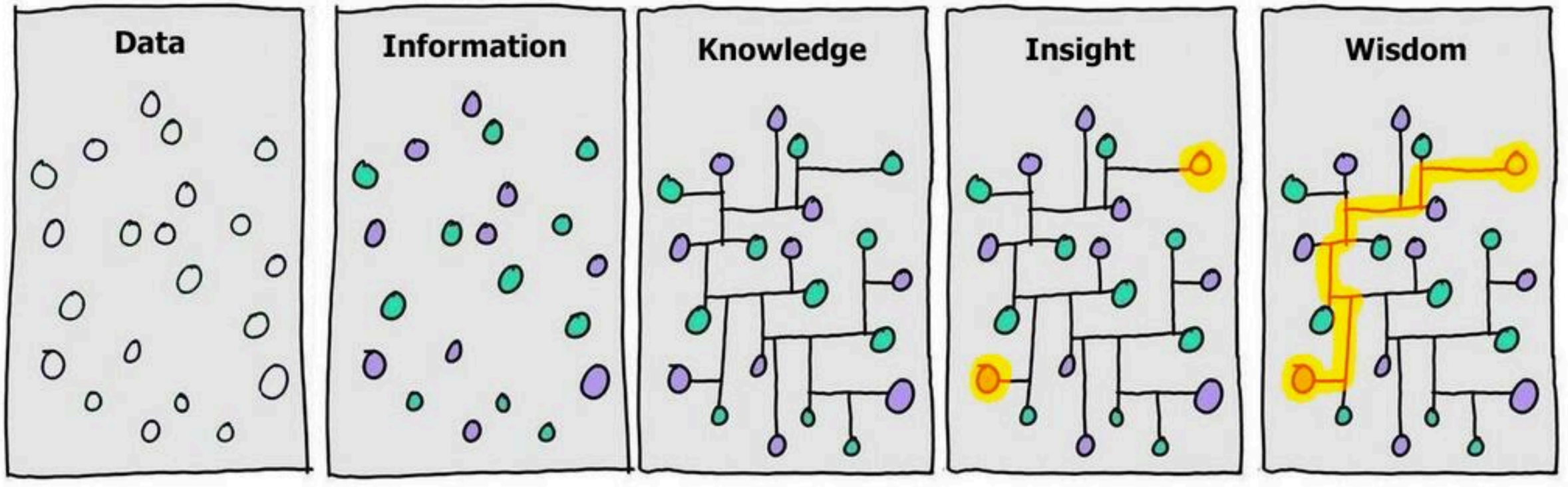
- Want to have results now
- How?
  - Faster machines
  - Clusters
  - Progressive techniques

What's involved in dealing with data?

Data Acquisition	Data Analysis	Data Curation	Data Storage	Data Usage
• Structured data • Unstructured data • Event processing • Sensor networks • Protocols • Real-time • Data streams • Multimodality	• Stream mining • Semantic analysis • Machine learning • Information extraction • Linked Data • Data discovery • 'Whole world' semantics • Ecosystems • Community data analysis • Cross-sectorial data analysis	• Data Quality • Trust / Provenance • Annotation • Data validation • Human-Data Interaction • Top-down/Bottom-up • Community / Crowd • Human Computation • Curation at scale • Incentivisation • Automation • Interoperability	• In-Memory DBs • NoSQL DBs • NewSQL DBs • Cloud storage • Query Interfaces • Scalability and Performance • Data Models • Consistency, Availability, Partition-tolerance • Security and Privacy • Standardization	• Decision support • Prediction • In-use analytics • Simulation • Exploration • Visualisation • Modeling • Control • Domain-specific usage

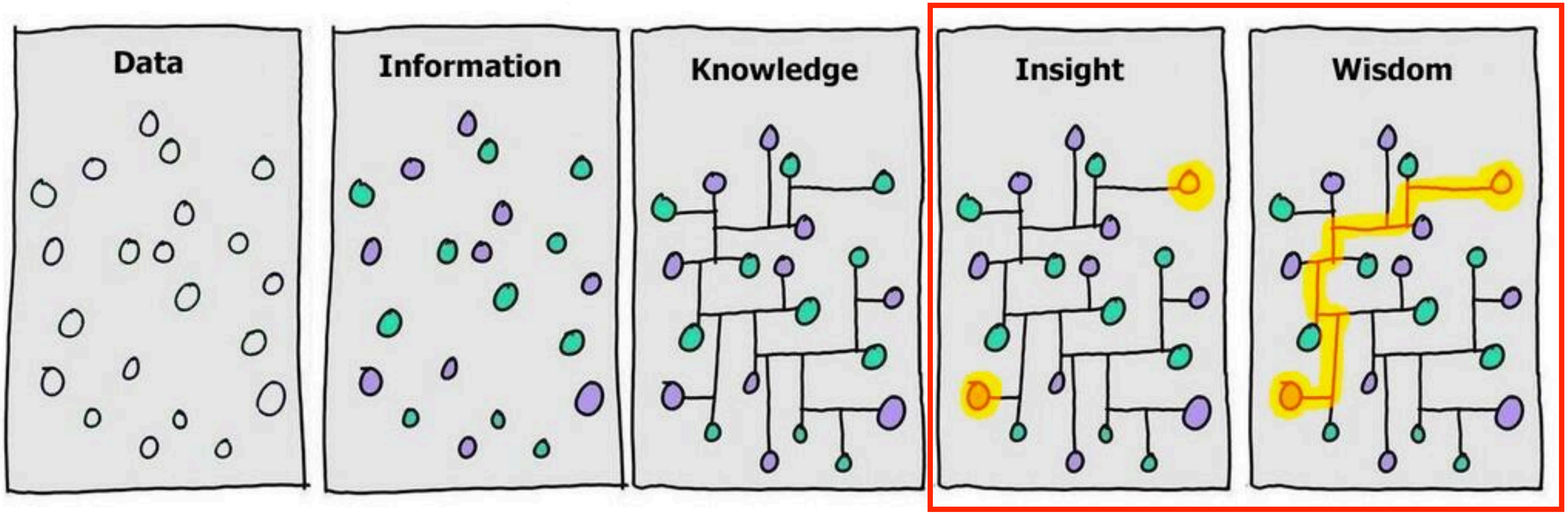
[Big Data Value Chain, Curry et al., 2014]

Data to Knowledge



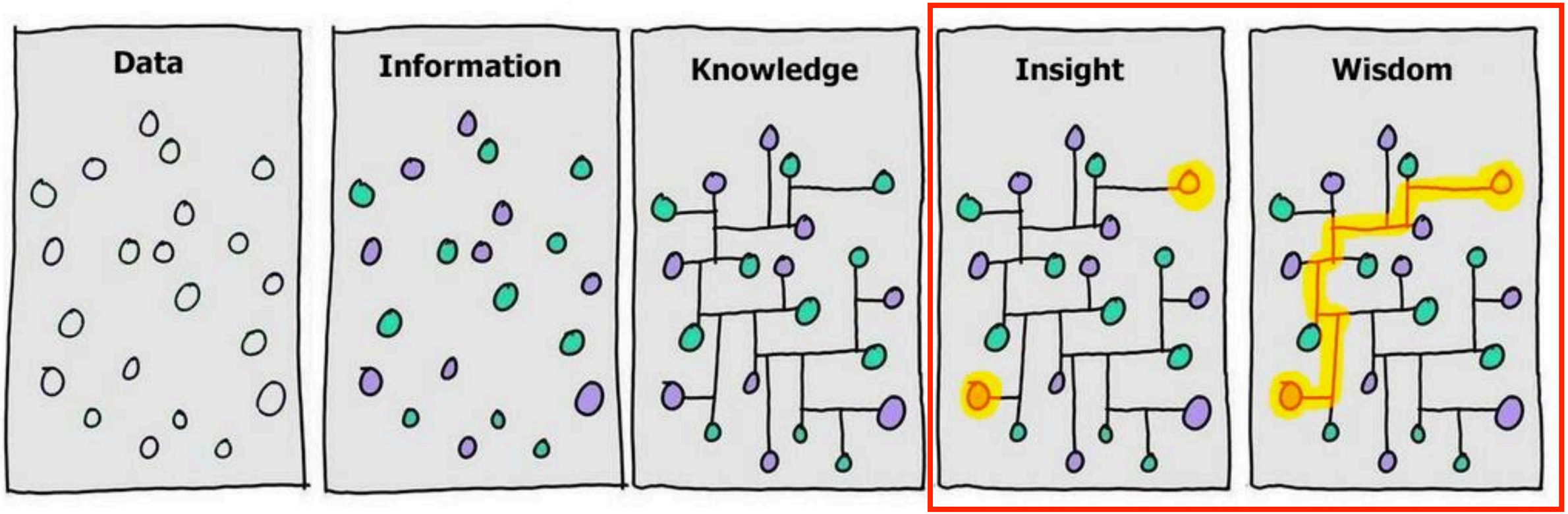
[D. Somerville, based on H. McLeod's original]

Data to Knowledge



[D. Somerville, based on H. McLeod's original]

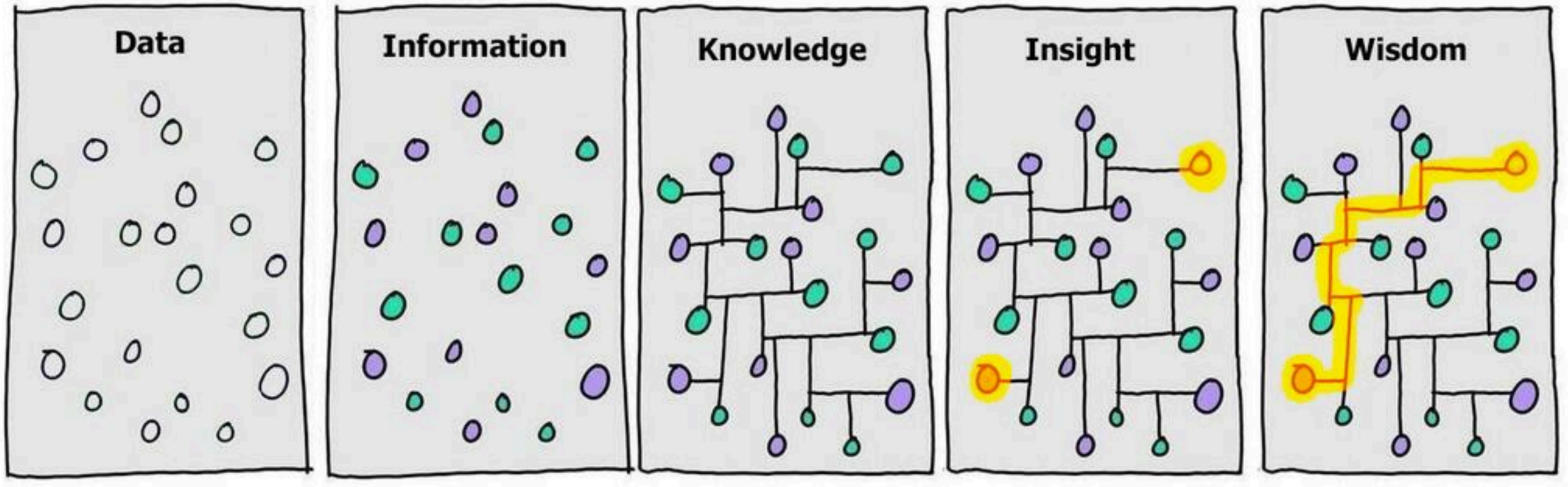
Data to Knowledge



Require People?

[D. Somerville, based on H. McLeod's original]

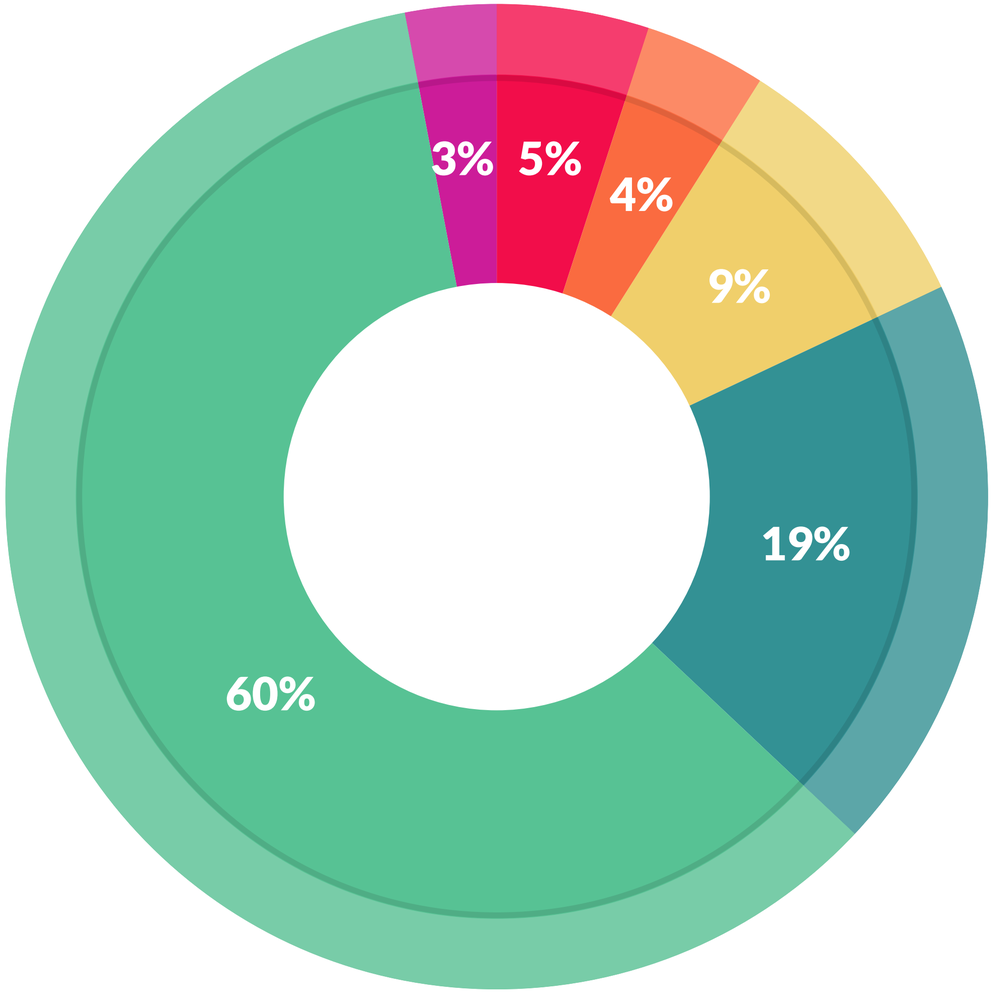
Data to Knowledge



What can computers help with?

[D. Somerville, based on H. McLeod's original]

How do data scientists spend their time?

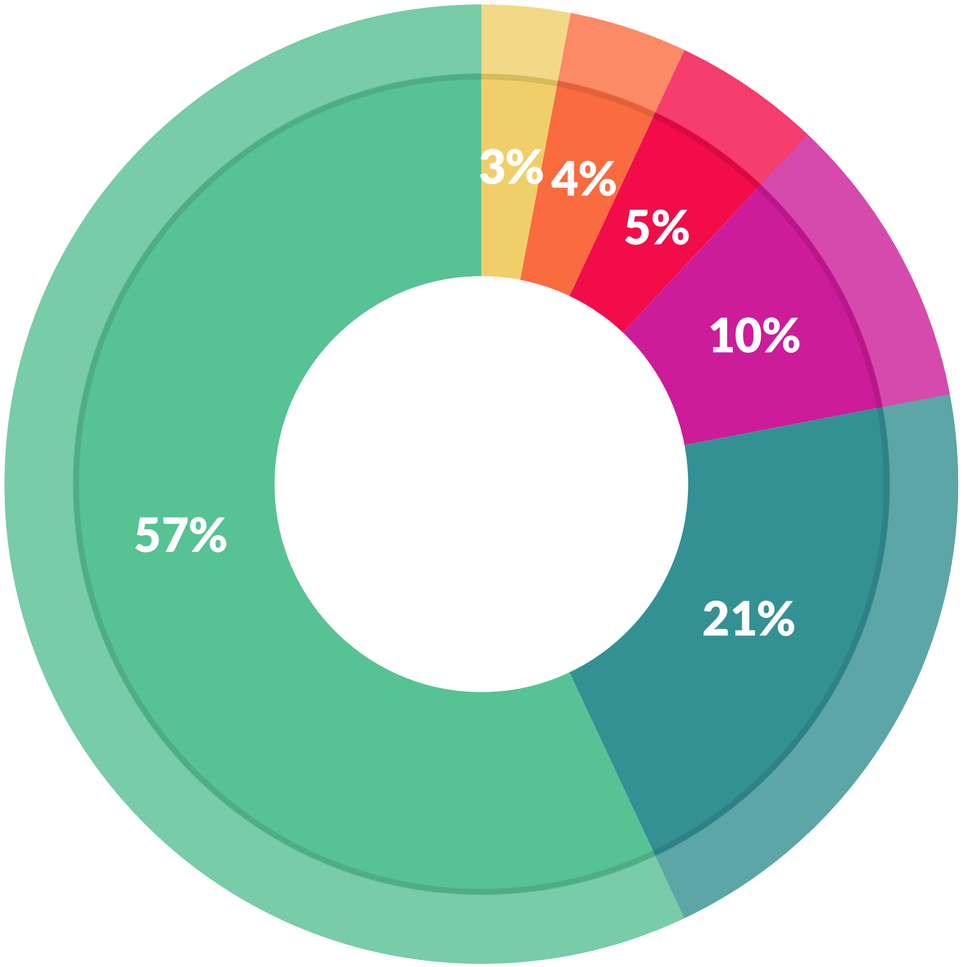


What data scientists spend the most time doing

- *Building training sets: 3%*
- *Cleaning and organizing data: 60%*
- *Collecting data sets; 19%*
- *Mining data for patterns: 9%*
- *Refining algorithms: 4%*
- *Other: 5%*

[CrowdFlower Data Science Report, 2016]

What do they like doing?

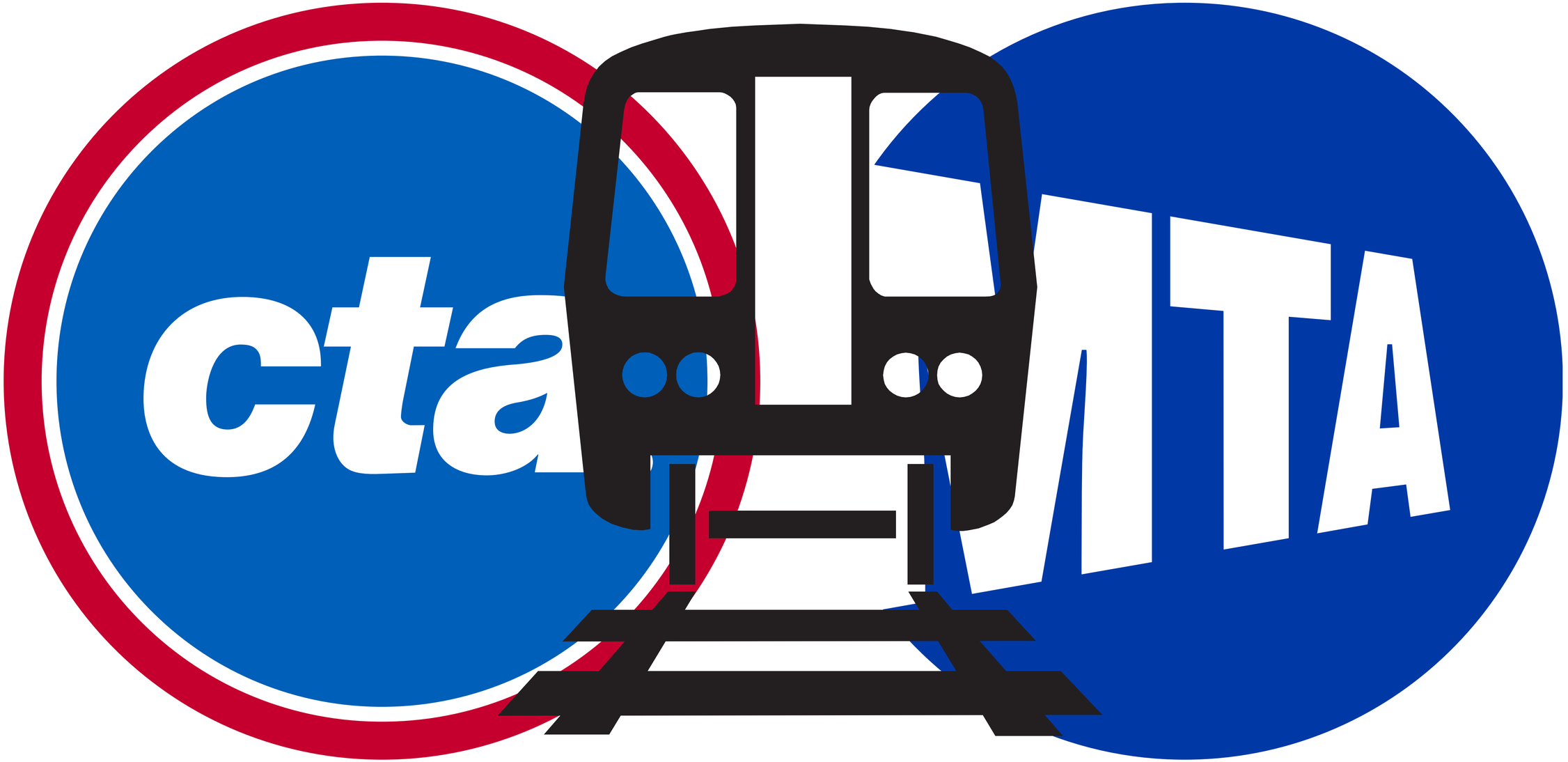


What's the least enjoyable part of data science?

- *Building training sets: 10%*
- *Cleaning and organizing data: 57%*
- *Collecting data sets: 21%*
- *Mining data for patterns: 3%*
- *Refining algorithms: 4%*
- *Other: 5%*

[CrowdFlower Data Science Report, 2016]

Example: Compare public transit in Chicago and NYC



Public Transit Ridership Data

station_id	stationname	date	daytype	rides
40350	UIC-Halsted	01/01/2001	U	273
41130	Halsted-Orange	01/01/2001	U	306
40760	Granville	01/01/2001	U	1,059
40070	Jackson/Dearborn	01/01/2001	U	649
40090	Damen-Brown	01/01/2001	U	411
40590	Damen/Milwaukee	01/01/2001	U	870
40720	East 63rd-Cottage Grove	01/01/2001	U	391
41260	Austin-Lake	01/01/2001	U	399
40230	Cumberland	01/01/2001	U	788
41120	35-Bronzeville-IIT	01/01/2001	U	448
40810	Medical Center	01/01/2001	U	479
40330	Grand/State	01/01/2001	U	2,542
41050	Linden	01/01/2001	U	176
40140	Skokie	01/01/2001	U	0
40450	95th/Dan Ryan	01/01/2001	U	3,948
40400	Noyes	01/01/2001	U	72
40150	Pulaski-Cermak	01/01/2001	U	0
40690	Dempster	01/01/2001	U	177
40460	Merchandise Mart	01/01/2001	U	185
40840	South Boulevard	01/01/2001	U	202
41280	Jefferson Park	01/01/2001	U	1,302
40130	51st	01/01/2001	U	364
40870	Francisco	01/01/2001	U	196
40710	Chicago/Franklin	01/01/2001	U	384
40740	Western-Cermak	01/01/2001	U	0
40550	Irving Park-O'Hare	01/01/2001	U	731

< Previous Next > Showing Rows 1-100 out of 962,546

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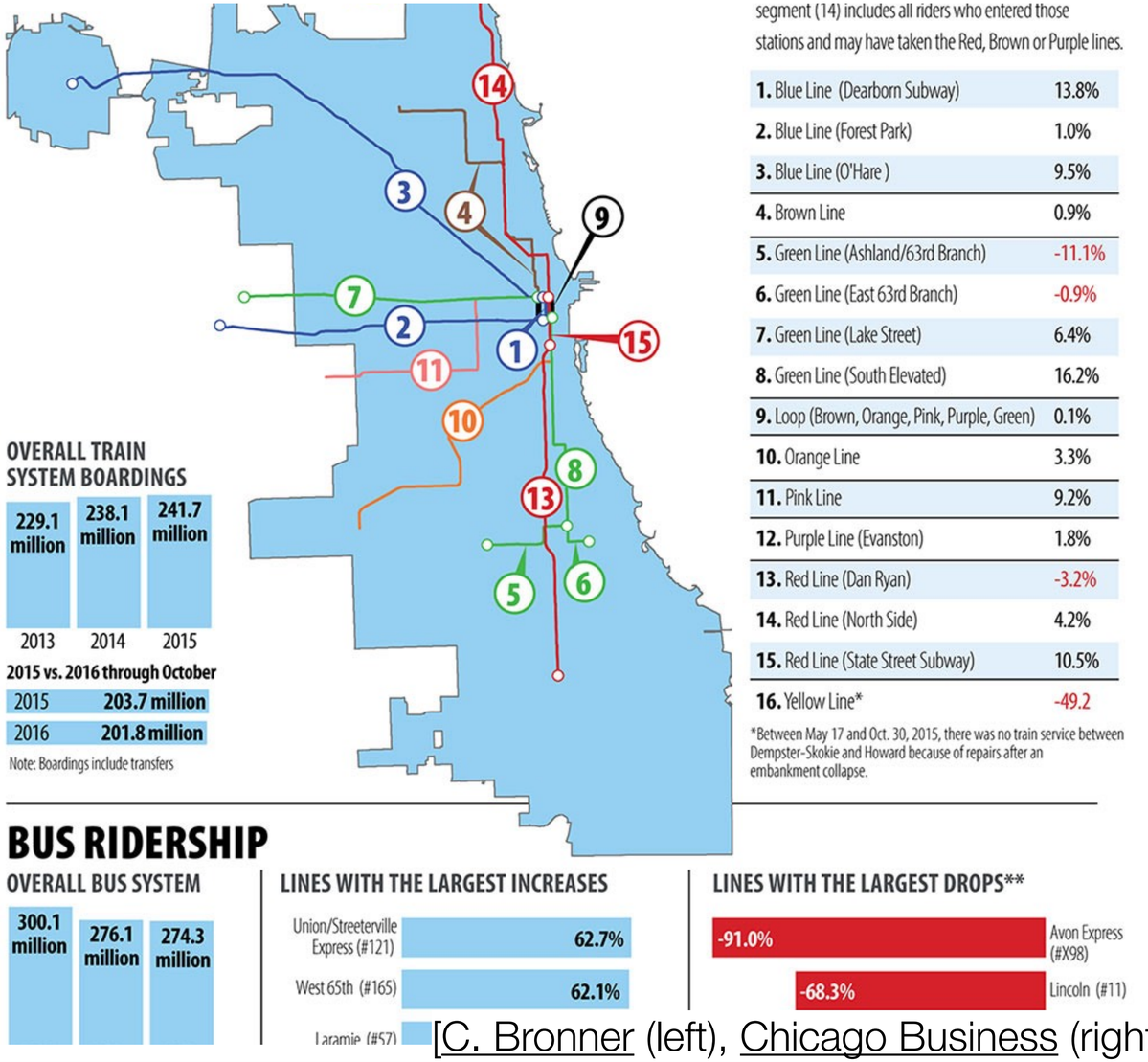
Cool Machine Learning Model & Pretty Visualizations



[C. Bronner (left), Chicago Business (right)]

Wait… how do we actually get those results?

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40350	UIC-Halsted	01/01/2001	U	273
41130	Halsted-Orange	01/01/2001	U	306
40760	Granville	01/01/2001	U	1,059
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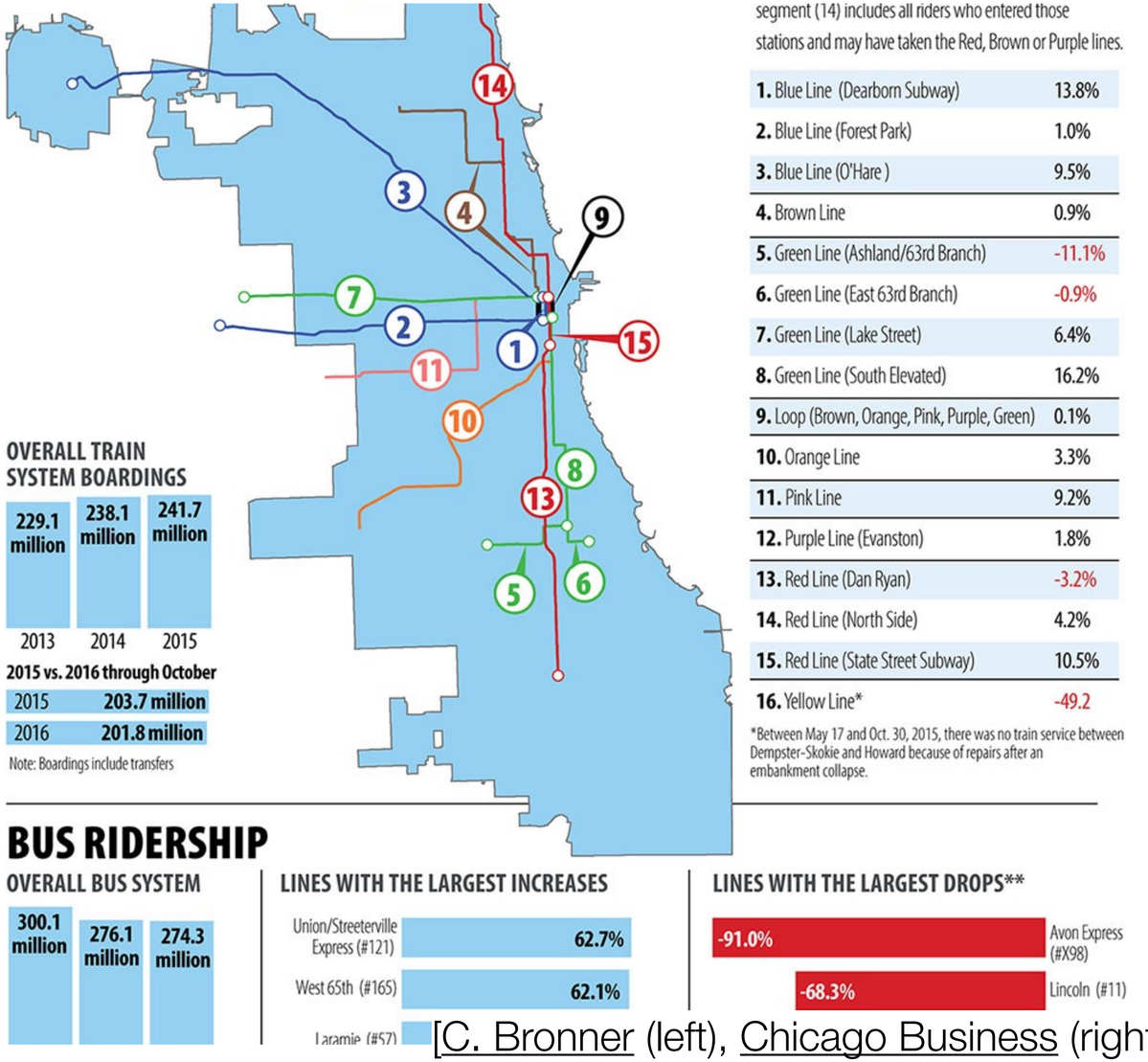
A002,R051,02-00-00,59
```

Processing the data

- Data Ingestion
  - Need to understand format of the data
  - Need to understand what the data is (types and semantics)
- Data Wrangling
  - Get the data into a meaningful state
  - Check for errors in the data
  - Check for missing data and deal with it
- Data Integration
  - Make it so we can actually compare the data
  - Put the datasets together

Cool Machine Learning Model & Pretty Visualizations



[C. Bronner (left), Chicago Business (right)]

Lots of topics related to this

Data Wrangling

	A	B	C	D
1	**Transaction Date**	**Customer Name**	**Phone Numbers**	**Address**
2	Wed, 12 Jan 2011	John K. Doe Jr.	(609)-993-3001	2196 184th Ave. NE, Redmond, 98052
3	Thu, 15 Sep 2011	Mr. Doe, John	609.993.3001 ext 2001	4297 148th Avenue NE, Bellevue, 98007
4	Mon, 17 Sep 2012	Jane A. Smith	+1-4250013981	2720 N Mesa St, El Paso, 79902, USA
5	2010-Nov-30 11:10:41	MS. Jane Smith	425 001 3981	3524 W Shore Rd APT 1002, Warwick
6	2011-Jan-11 02:27:21	Smith, Jane	tel: 4250013981	4740 N 132nd St Apt 417, Omaha, 68164
7	2011-Jan-12	Anthony R Von Fange II	650-384-9911	10508 Prairie Ln, Oklahoma City
8	2010-Dec-24	Mr. Peter Tyson	(405)123-3981	525 1st St, Marysville, WA 95901
9	9/22/2011	Dan E. Williams	1-650-1234183	211 W Ridge Dr, Waukon,52172
10	7/11/2012	James Davis Sr.	+1-425-736-9999	13120 Five Mile Rd, Brainerd
11	2/12/2012	Mr. James J. Davis	425.736.9999 x 9	602 Highland Ave, Shinnston, 26431
12	3/31/2013	Donald Edward Miller	(206) 309-8381	840 W Star St, Greenville, 27834
13	6/1/2009 12:01	Miller, Donald	206 309 8381	25571 Elba, Redford, 48239
14	2/26/2007 18:37	Rajesh Krishnan	206 456 8500 extension 1	539 Co Hwy 48, Sikeston, USA
15	1/4/2011 14:33	Daniel Chen	425 960 3566	1008 Whitlock Ave NW, Marietta, 30064

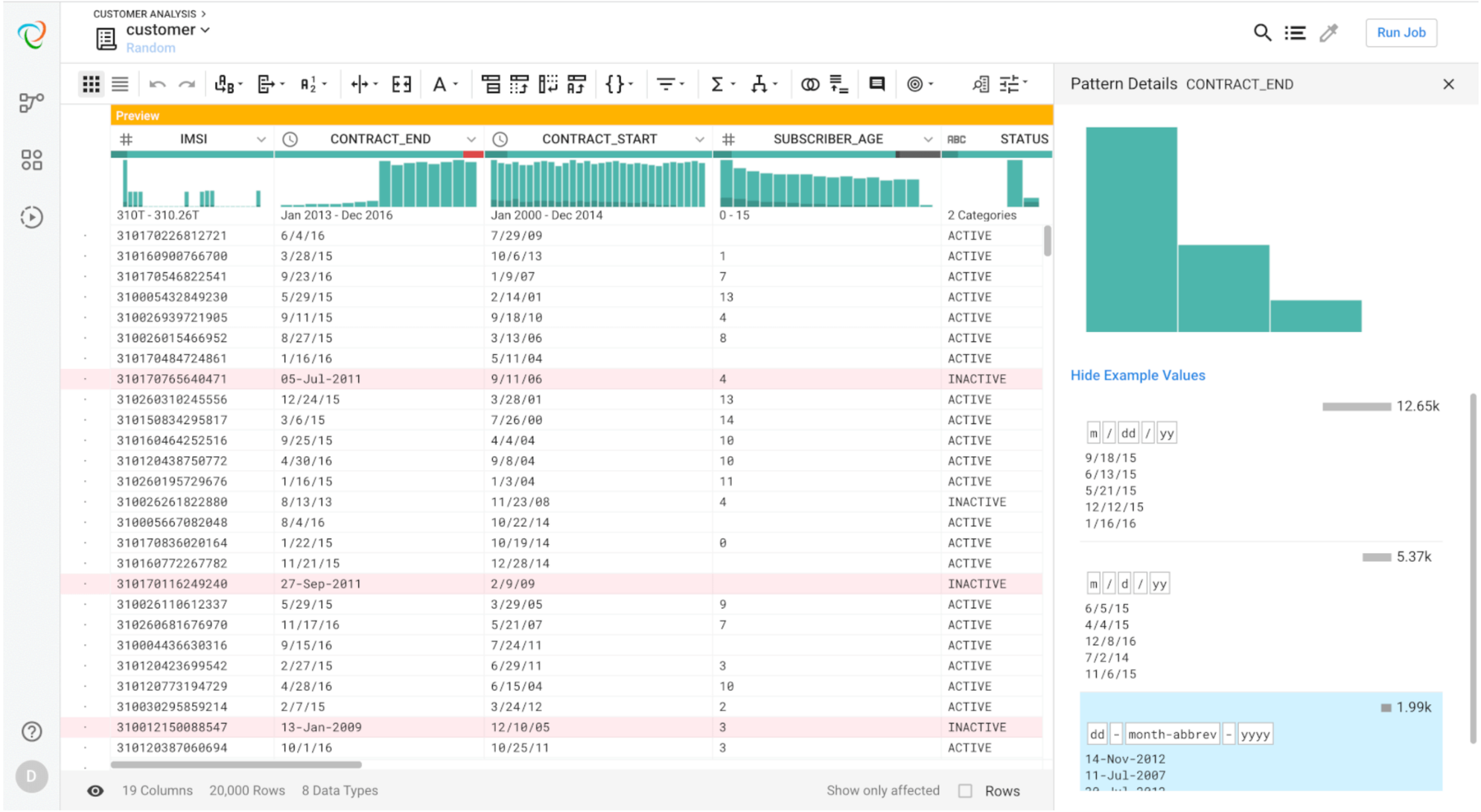
C	D
Transaction Date	**output**
Wed, 12 Jan 2011	2011-01-12-Wednesday
Thu, 15 Sep 2011	2011-09-15-Thursday
Mon, 17 Sep 2012	2012-09-17-Monday
2010-Nov-30 11:10:41	2010-11-30-Tuesday
2011-Jan-11 02:27:21	2011-01-11-Tuesday
2011-Jan-12	2011-01-12-Wednesday
2010-Dec-24	2010-12-24-Friday
9/22/2011	2011-09-22-Thursday
7/11/2012	2012-07-11-Wednesday
2/12/2012	2012-02-12-Sunday

C	D
Customer Name	**Output**
John K. **Doe** Jr.	Doe, John
Mr. **Doe**, **John**	Doe, John
Jane A. **Smith**	Smith, Jane
MS. **Jane Smith**	Smith, Jane
Smith, **Jane**	Smith, Jane
Dr **Anthony** R **Von Fange** III	Von Fange, Anthony
Peter Tyson	Tyson, Peter
Dan E. **Williams**	Williams, Dan
James Davis Sr.	Davis, James
James J. **Davis**	Davis, James
Mr. **Donald** Edward **Miller**	Miller, Donald

C	D
Address	**Output**
2196 184th Ave. NE Apt 417, **Redmond, 98052**	Redmond, WA, 98052
4297 148th Avenue NE L105, **Bellevue, WA 98007**	Bellevue, WA, 98007
2720 N Mesa St, **El Paso, 79902, USA**	El Paso, TX, 79902
3524 W Shore Rd APT 1002, **Warwick,02886**	Warwick, RI, 02886
4740 N 132nd St, **Omaha, 68164**	Omaha, NE, 68164
10508 Prairie Ln, **Oklahoma City**	Oklahoma City, OK, 73162
525 1st St, **Marysville, WA 95901**	Marysville, CA, 95901
211 W Ridge Dr, **Waukon,52172**	Waukon, IA, 52172
602 Highland Ave, **Shinnston, 26431**	Shinnston, WV, 26431
840 W Star St, **Greenville, 27834**	Greenville, NC, 27834

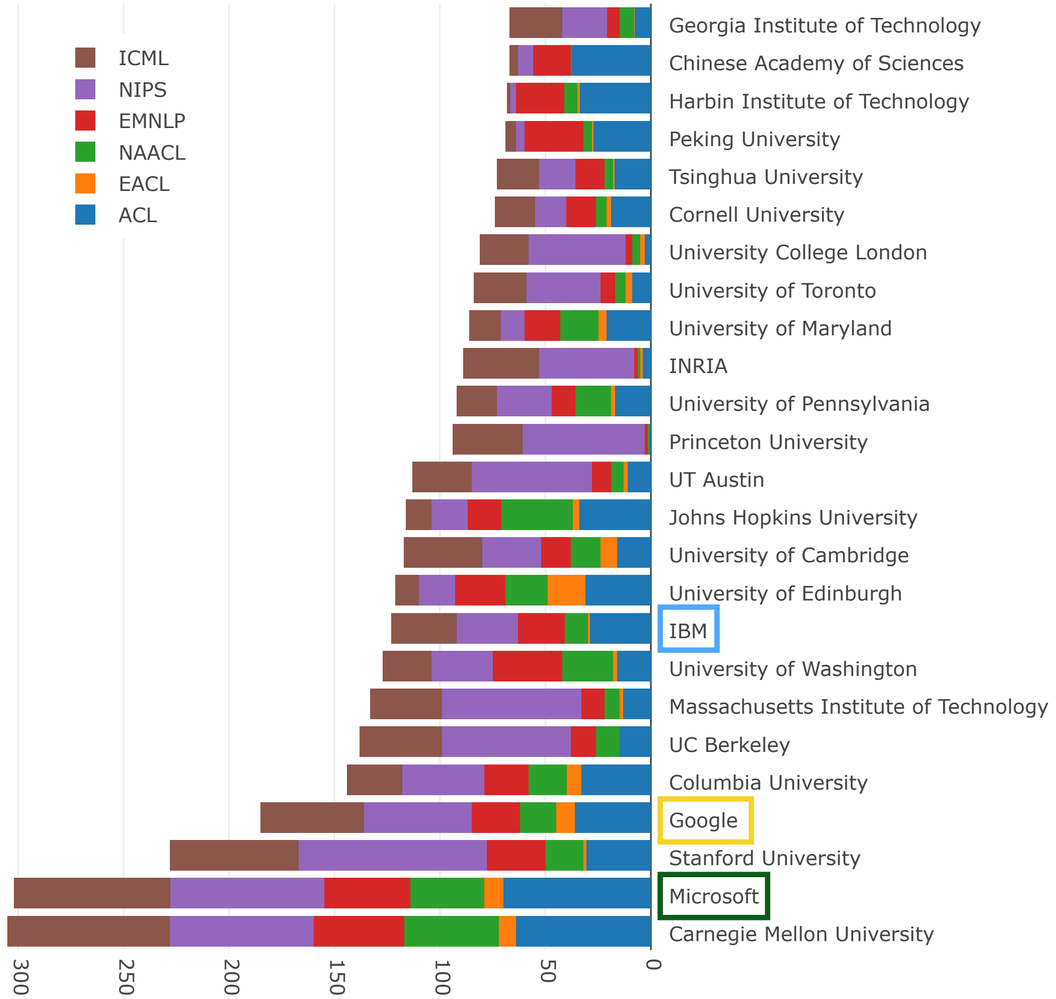
[Y. He et al., 2018]

Data Wrangling



[Trifacta]

Data Cleaning/Standardization (Aliases)

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'ibm tj watson research center':'ibm',
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'microsoft research maluuba':'microsoft',
'microsoft research new england':'microsoft',
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'miicrosoft research':'microsoft',
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[NLP Publishing Stats, M. Rei & R. Allen]

Data Integration: Entity Resolution

All topics

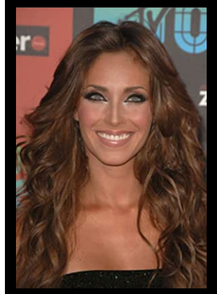
Anahí

Actress · Music Department · Soundtrack

Play trailer 2:59

Double Life (2011–2012)

1 VIDEO | 1 PHOTO



Anahi was born in Mexico. She's had roles in Tu y Yo, in which she played a 17 year old girl while she was 13, and Vivo Por Elena, in which she played Talita, a naive and innocent teenager. Anahi lives with her mother and sister name Marychelo. She hopes to become a fashion designer one day, and is currently… ›

Born May 14, 1982

IMDbPro STARMETER **See rank**

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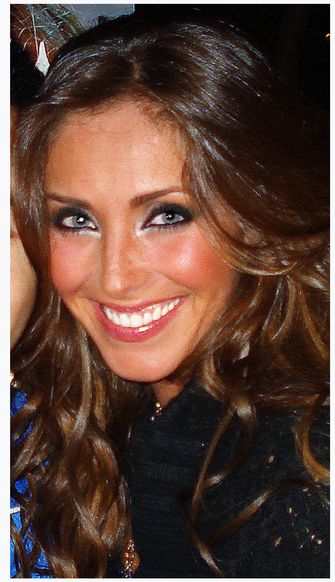
Anahí



Anahí in 2009.

Born	Anahí Giovanna Puente Portilla 14 May 1983 (age 39) Mexico City, Mexico
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Children	2
	Musical career
Genres	Latin pop · pop rock · dance-pop · pop
Instrument(s)	Vocals
Labels	Universal · Capitol
Formerly of	RBD

Data Integration: Entity Resolution

All topics

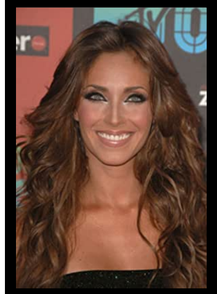
Anahí

Actress · Music Department · Soundtrack

Play trailer 2:59

Double Life (2011–2012)

1 VIDEO | 1 PHOTO



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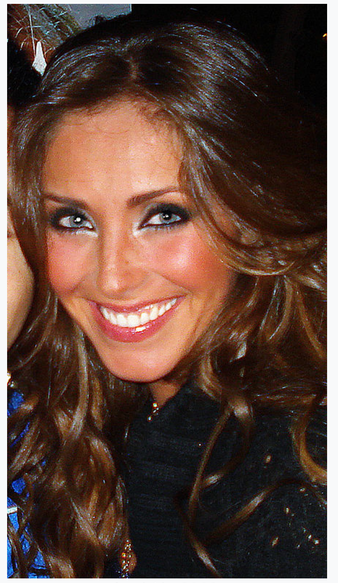

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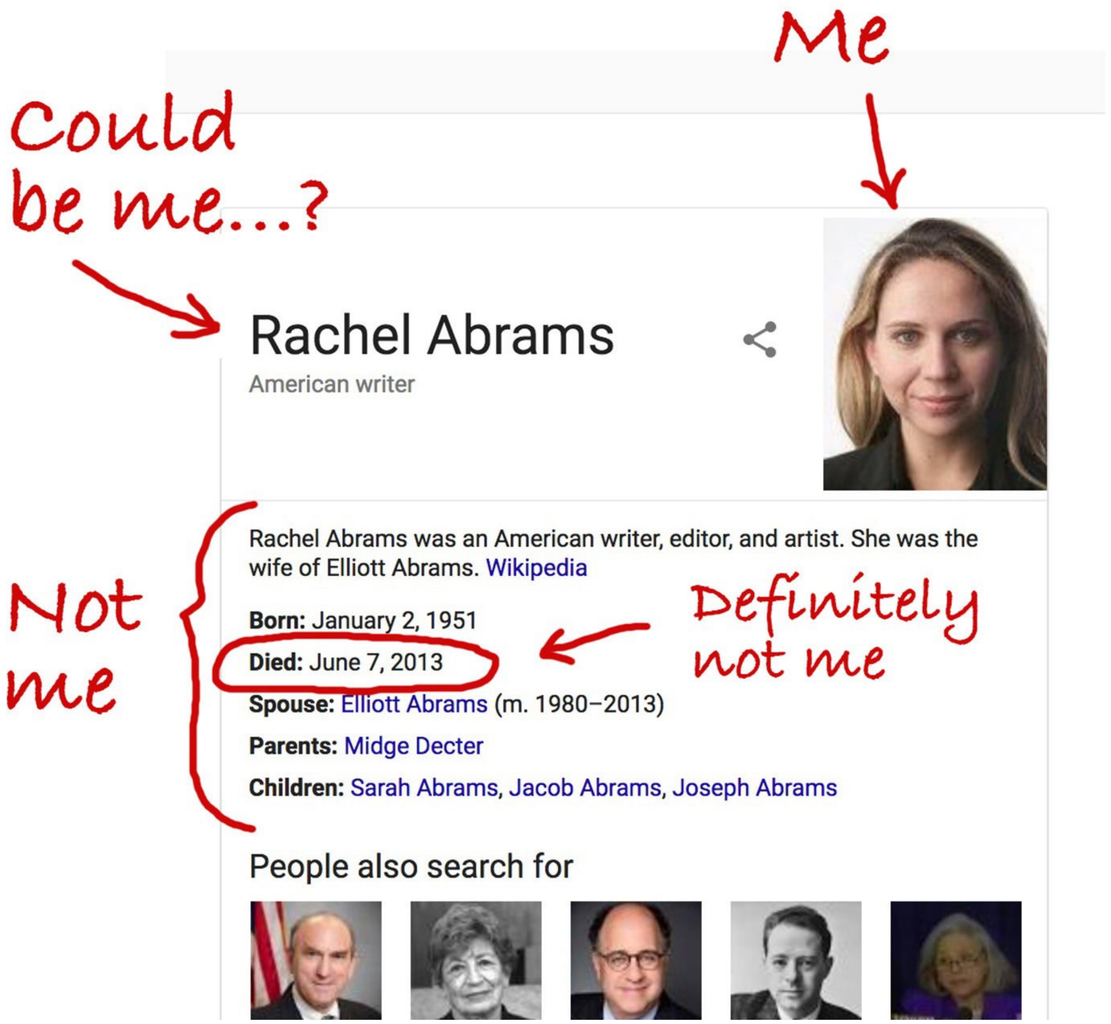
Labels	Universal · Capitol
Formerly of	RBD

Data Integration: Entity Resolution

- Google Thinks I'm Dead (I know otherwise.) [R. Abrams, NYTimes, 2017]
- Not only Google, but also Alexa:
  - "Alexa replies that Rachel Abrams is a sprinter from the Northern Mariana Islands (which is true of someone else)."
  - "He asks if Rachel Abrams is deceased, and Alexa responds yes, citing information in the Knowledge Graph panel."



Data Integration: Data Fusion

All topics

Anahí

Actress · Music Department · Soundtrack

Play trailer 2:59

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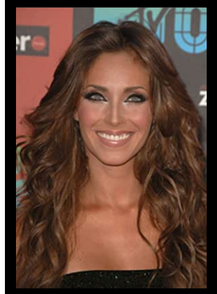
1 VIDEO | 1 PHOTO



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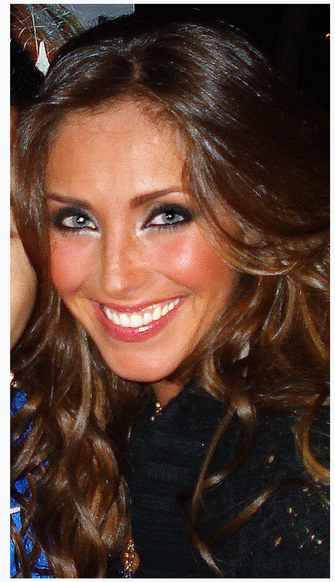

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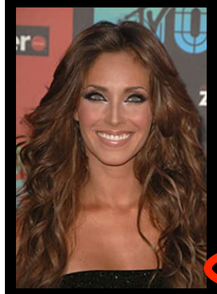

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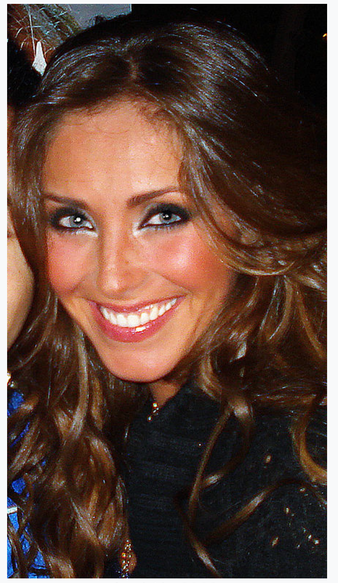

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Data Integration: Data Fusion

Source Observations

Source	River	Attribute	Value
KG	Mississippi River	Length	2,320 mi
KG	Missouri River	Length	2,341 mi
Wikipedia	Mississippi River	Length	2,202 mi
Wikipedia	Missouri River	Length	2,341 mi
USGS	Mississippi River	Length	2,340 mi
USGS	Missouri River	Length	2,540 mi

Fact

Conflicting value

Source reports a value for a fact

True Facts

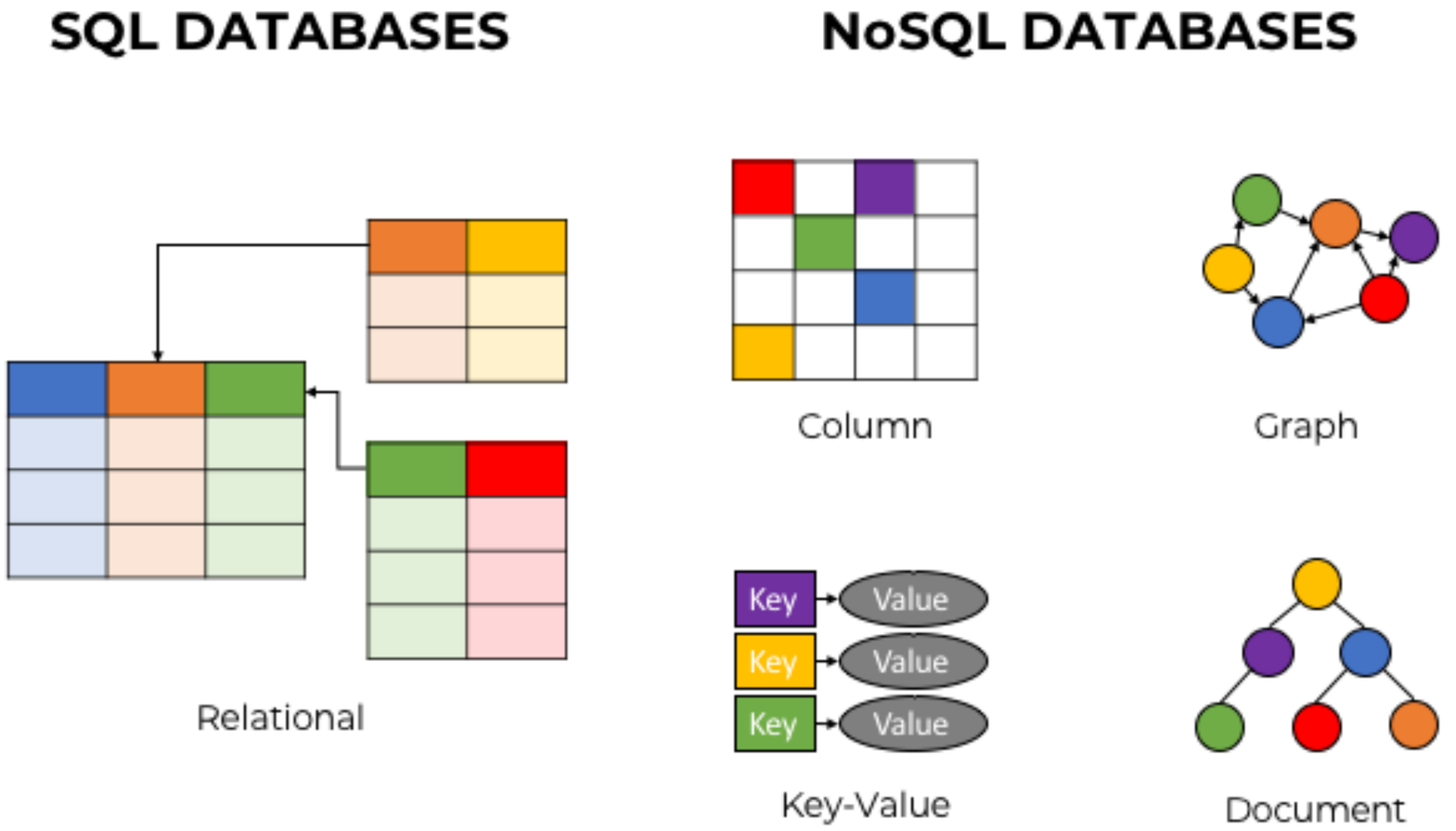
River	Attribute	Value
Mississippi River	Length	?
Missouri River	Length	?

Fact's true value

Goal: Find the **latent** true value of facts.

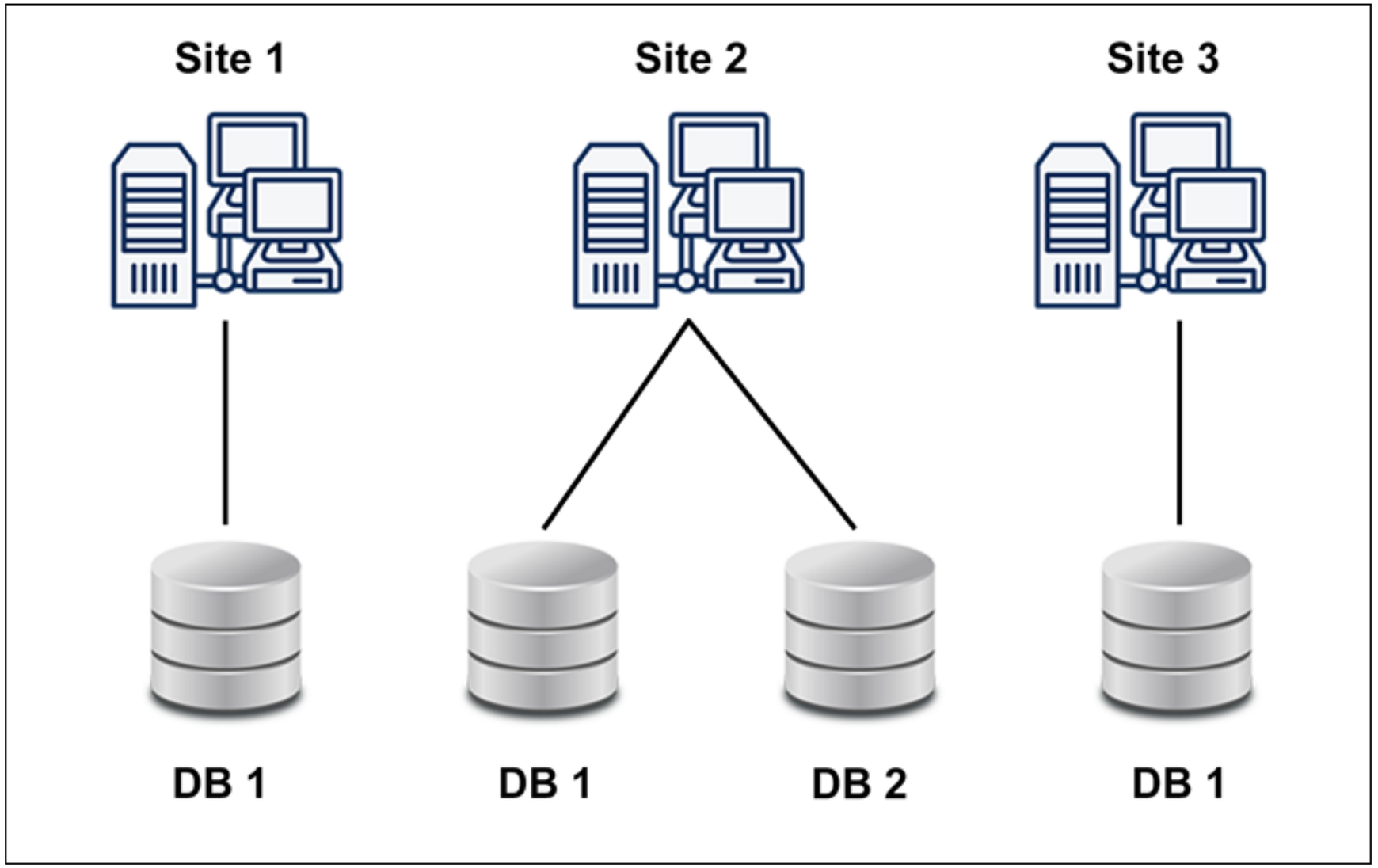
[X. L. Dong & T. Rekatsinas, 2019]

Data Storage



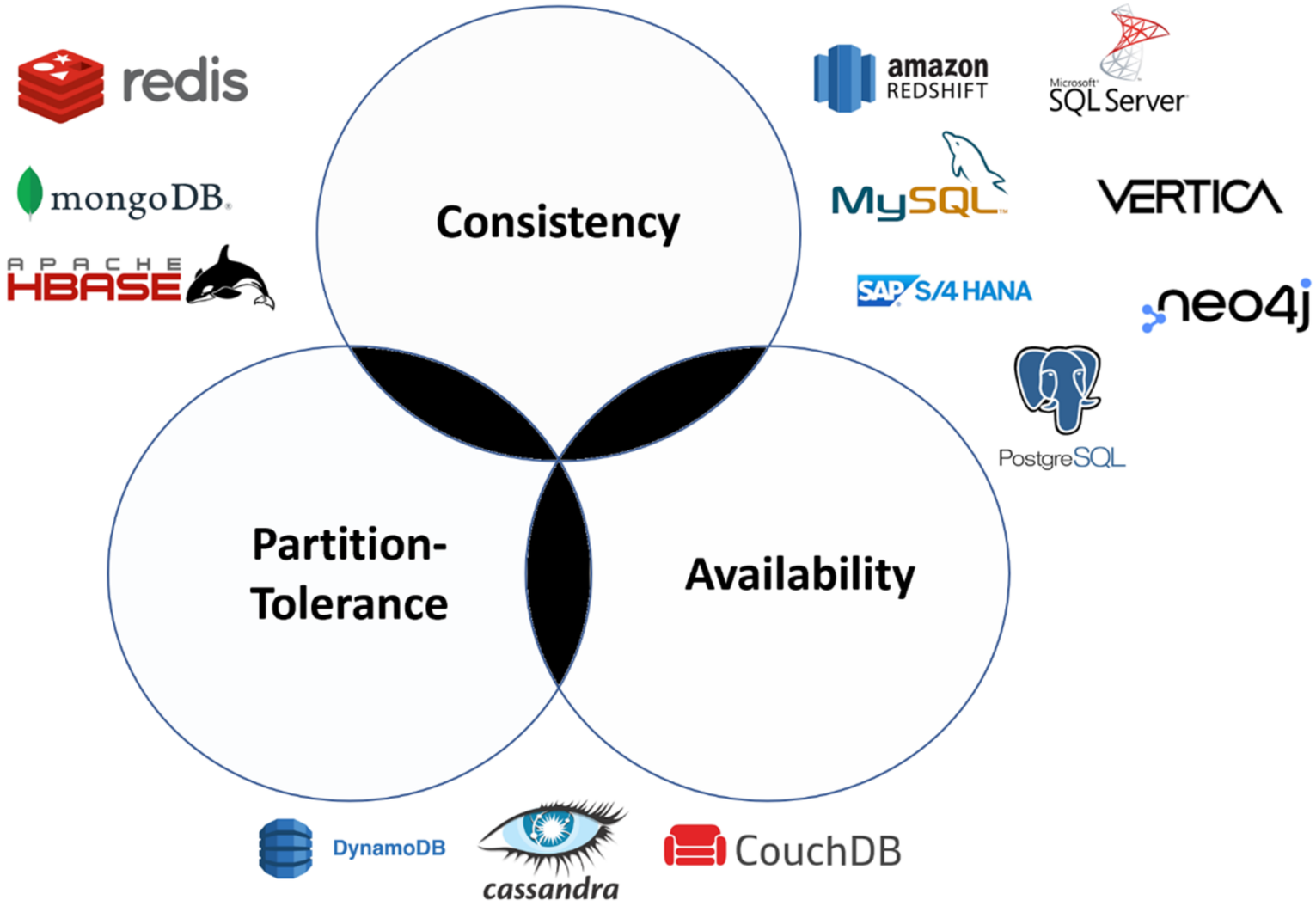
[V. Wilkinson]

Distributed Databases



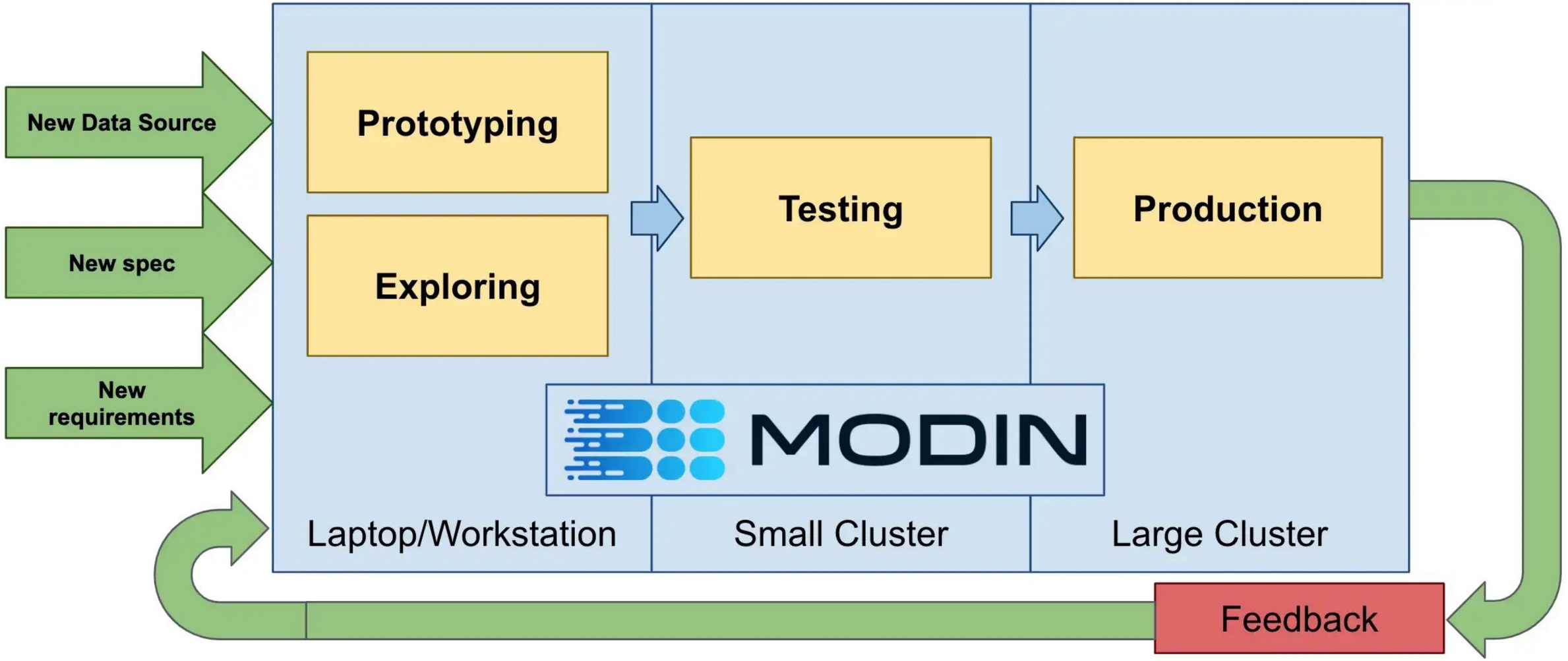
[phoenixNap]

CAP Theorem



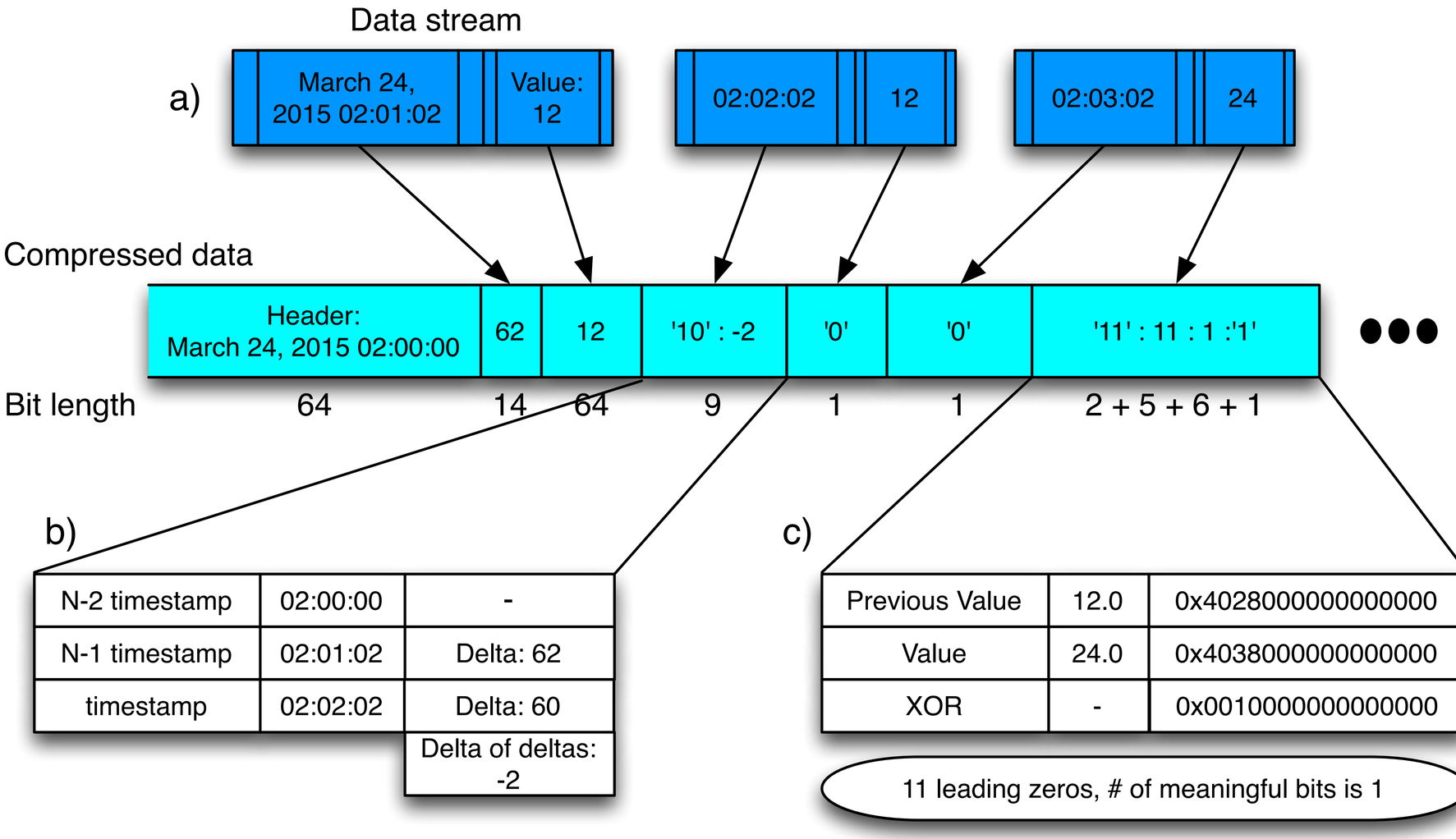
[B. Aunkofer]

Scaling Dataframes



[D. Petersohn]

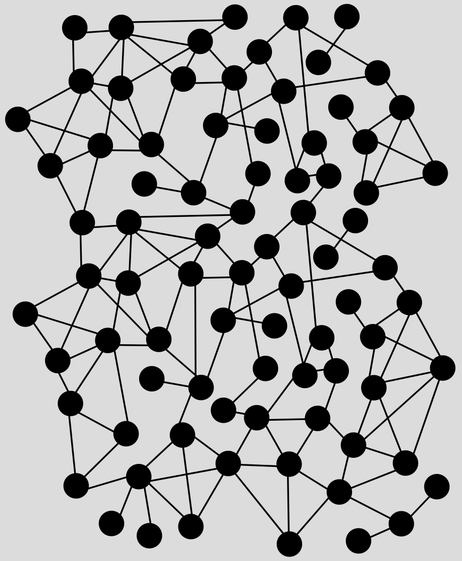
Representing Time Series Data



[Pelkonen et al.]

Representing Graph Data

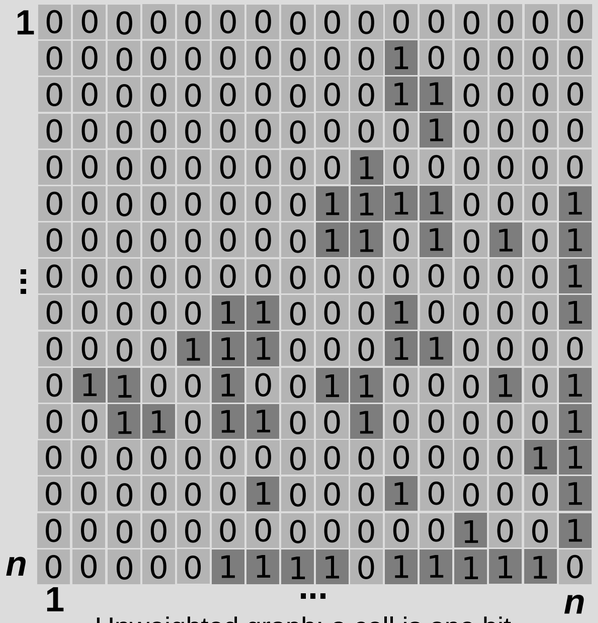
INPUT GRAPH:



n: number of vertices
m: number of edges
d: maximum graph degree

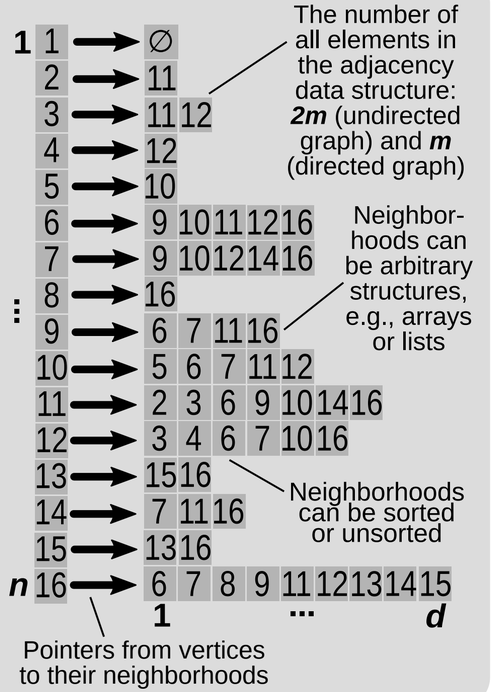
Adjacency Matrix

An ***n*** x ***n*** matrix

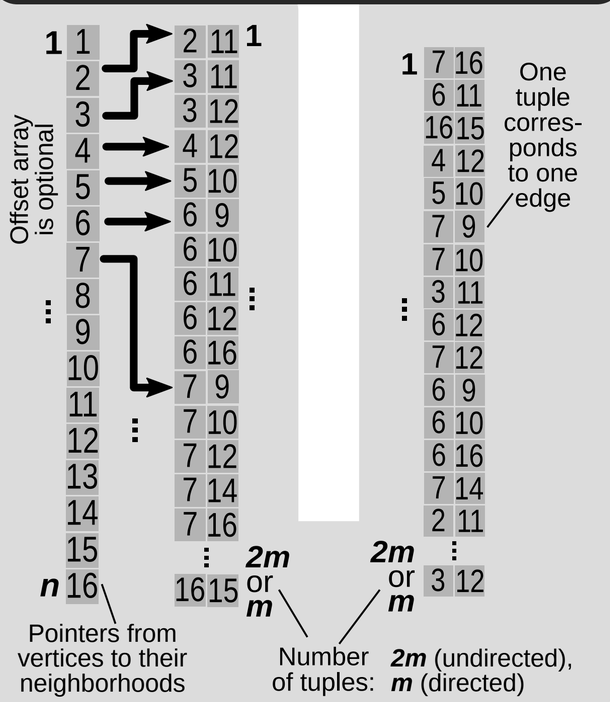


Unweighted graph: a cell is one bit
Weighted graph: a cell is one integer

Adjacency List

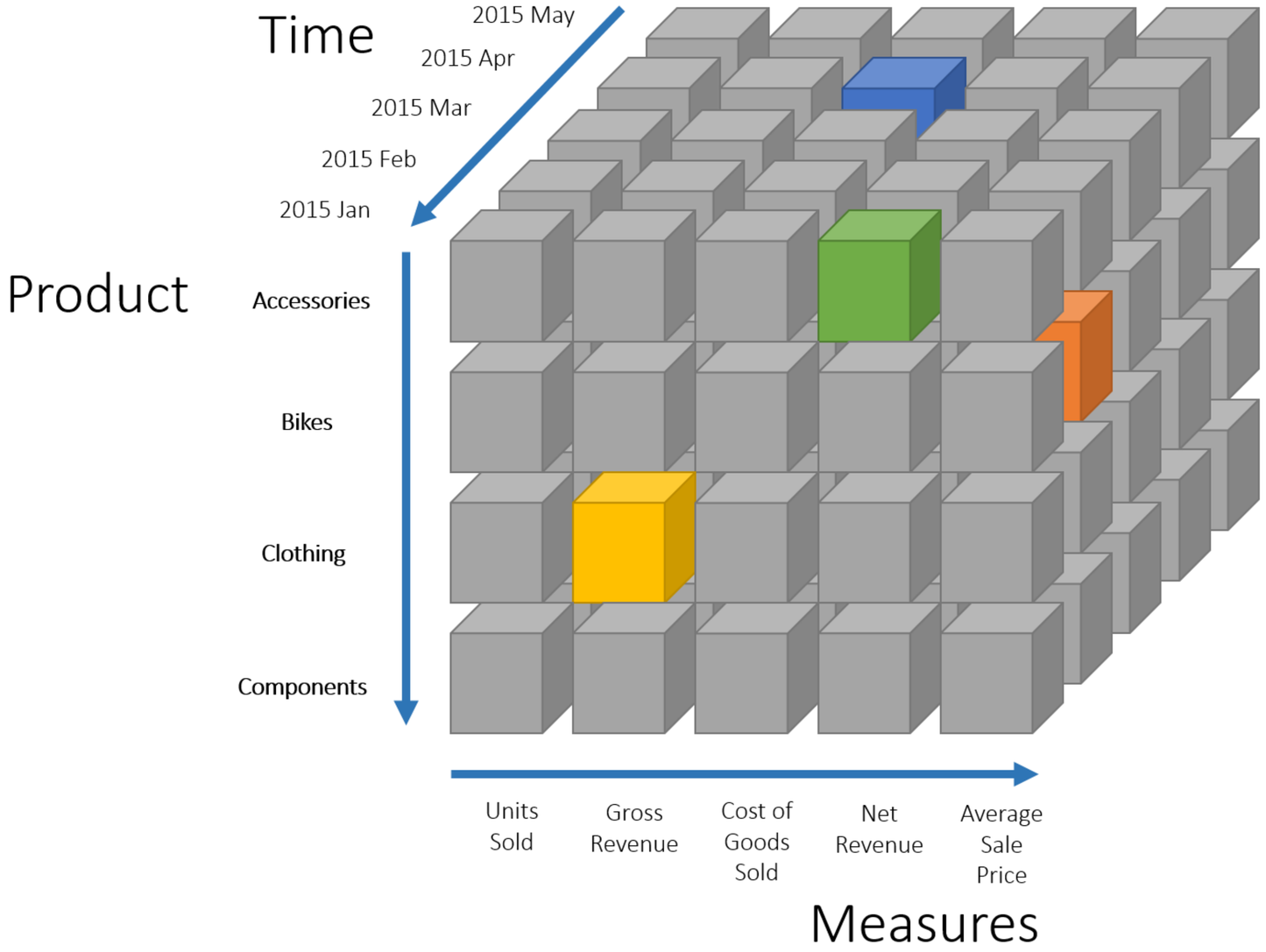


Edge List (sorted & unsorted)



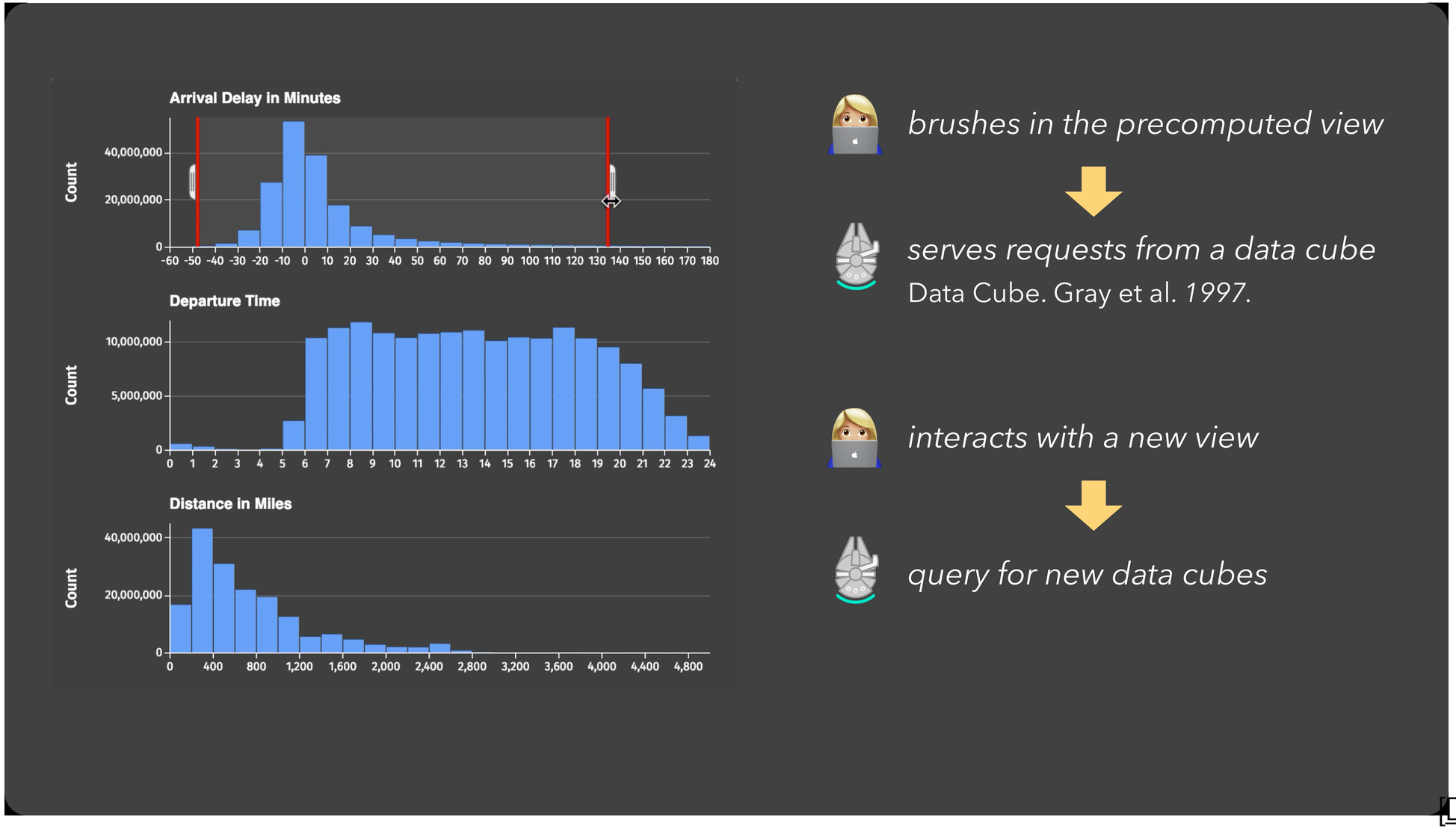
[M. Besta et al.]

Data Cubes



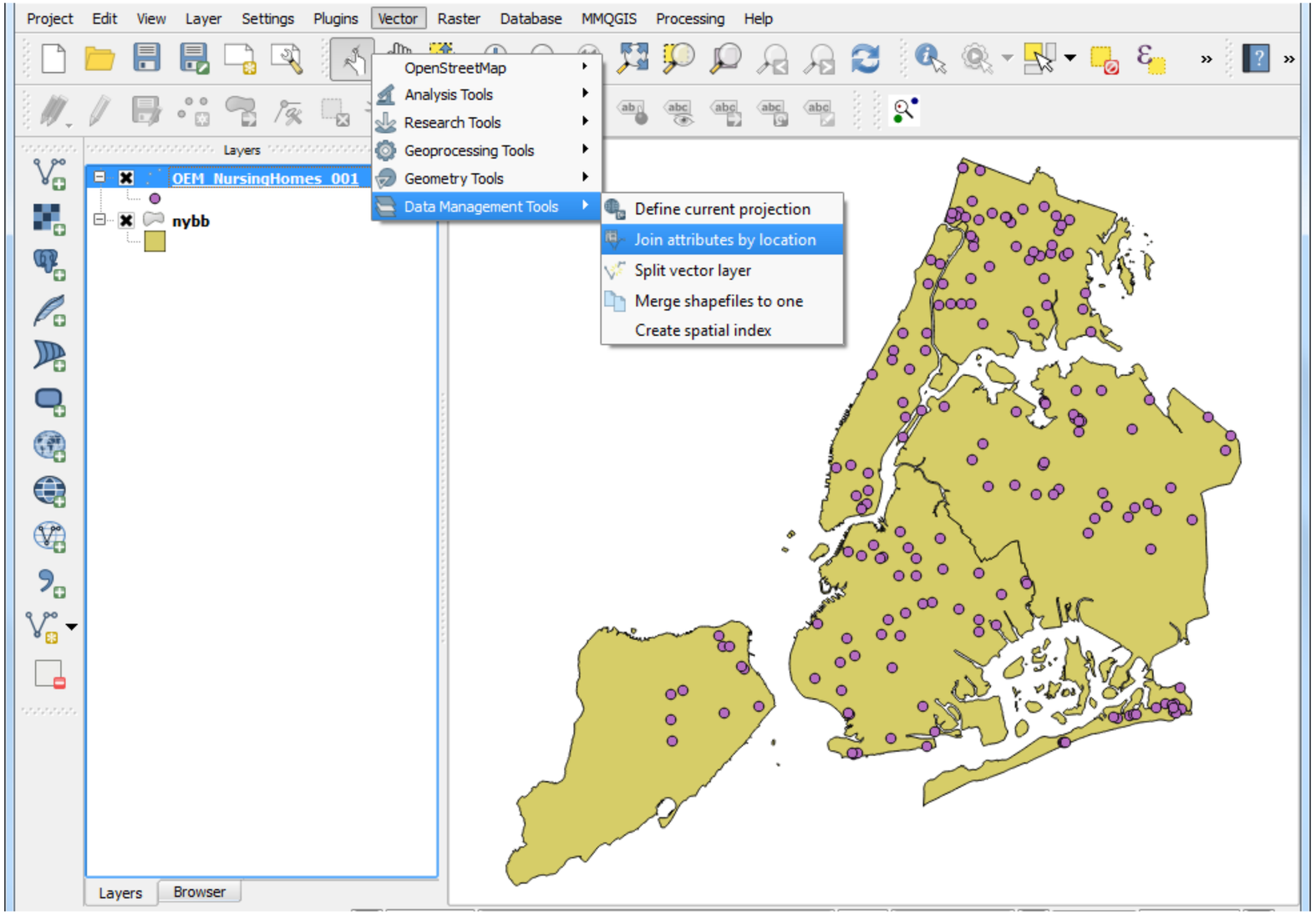
[M. K. Hernandez]

Visualization and Databases



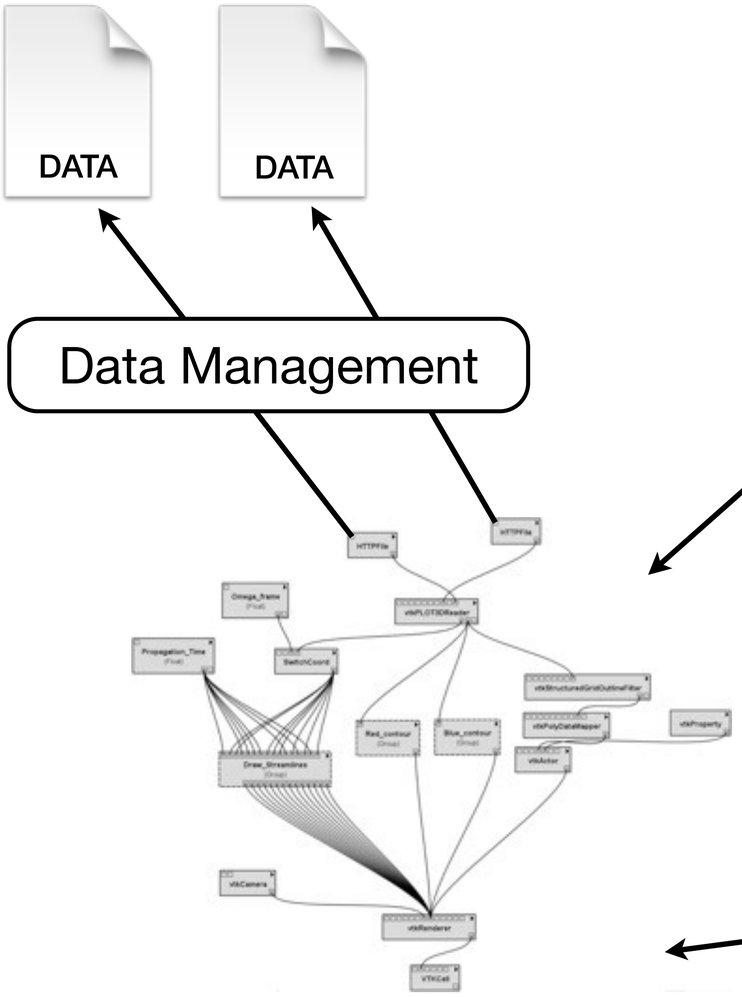
[D. Mortiz et al.]

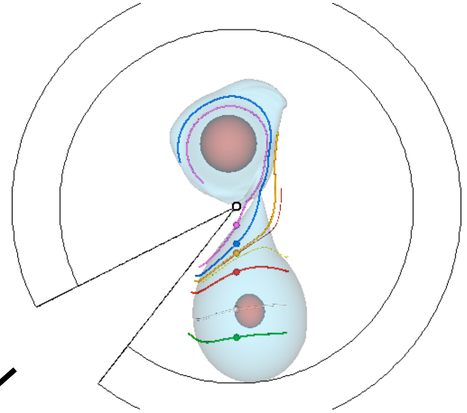
Spatial Data



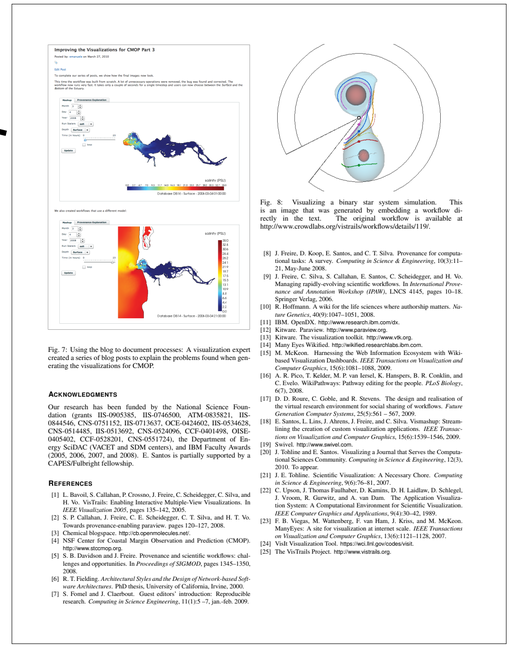
[QGIS Tutorials]

Provenance and Reproducibility





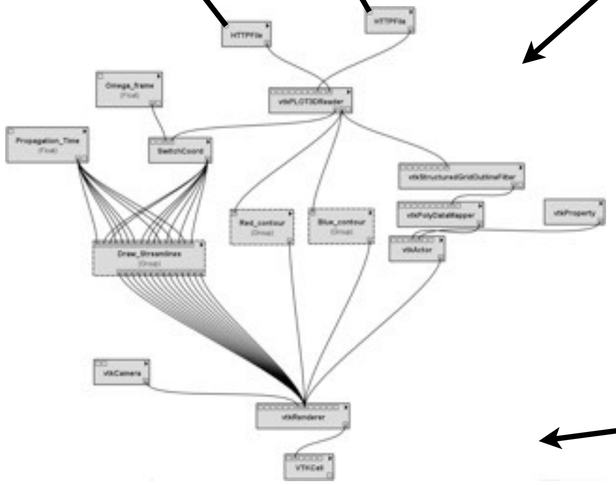
Visualization



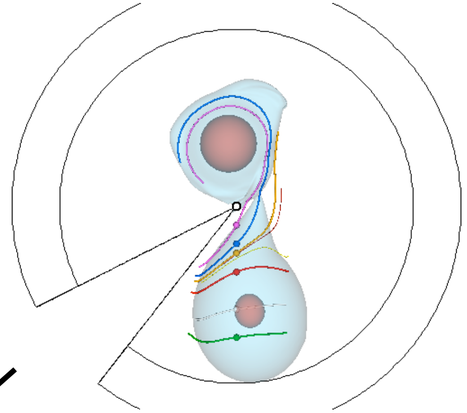
Paper

Provenance and Reproducibility

Data Management



Computation



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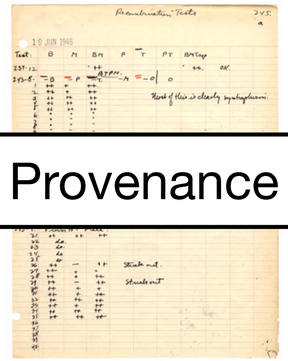
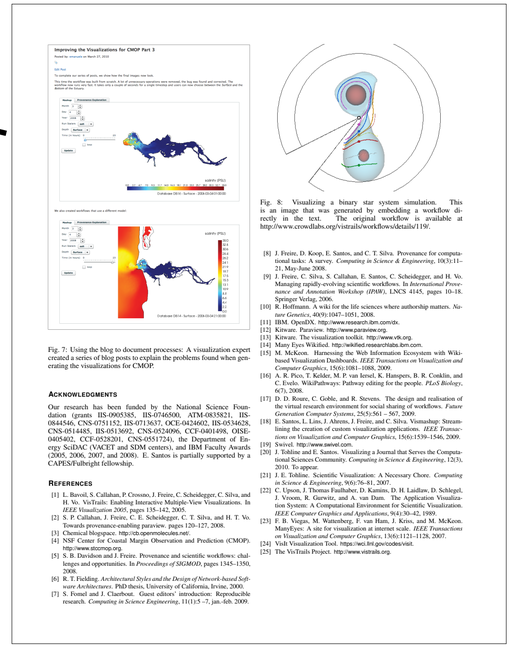


Provenance



Paper

About Me

- Research Interests
  - Visualization
  - Computational Provenance
  - Geospatial Analysis
- Research Projects
  - Dataflow Notebooks
  - Geospatial Trajectory Data
  - Provenance for Web Applications
- See my web page for more information
  - http://faculty.cs.niu.edu/~dakoop/

About You

- Research Papers?
- Data Science?
- Python?
- Database Experience?
- Analytics Experience?
- Cloud Computing Experience?
- Anything you want to see covered?

About this course

- Course web page is authoritative:
  - http://faculty.cs.niu.edu/~dakoop/cs640-2023sp/
  - Schedule, Readings, Assignments will be posted online
  - Check the web site before emailing me
- Lectures planned for in-person
- Course is meant to be more "cutting edge"
  - Focus on building skills related to data management
  - Tune into current research and tools
- Requires student participation: readings and discussions

About this course

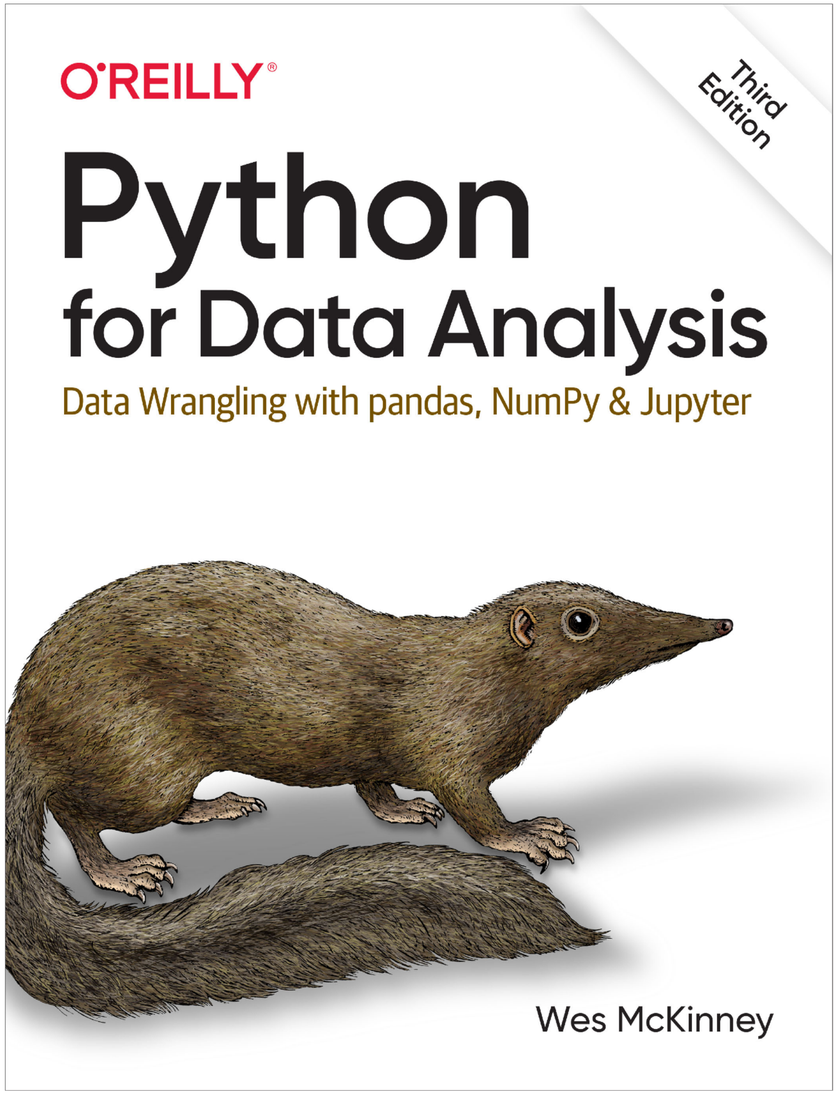
- Balance of techniques and research ideas
- Background (Python & Relational DB) followed by topic areas & readings
- Programming assignments (4-5)
- Two tests + final exam: Please check these dates now
- Topic areas:
  - Data Wrangling
  - Data Cleaning, Integration, & Fusion
  - Scalable Data Management (Databases & Dataframes) + Cloud
  - Spatial, Graph, Time Series Data
  - Provenance and Reproducibility

About this course

- Course Registration:
  - Make sure you have registered for the course
  - Email me if you are not registered but are interested in taking the course
- Undergraduate (CS 490) and Graduate (CS 640)
  - Grad students have extra reading, exam questions, assignment tasks
- Review of course policies:
  - Plagiarism and academic honesty
  - If you have any concerns or questions, please email me as soon as possible
- If you are not sure if this course is a good fit, please email me or talk to me

Course Material

- Helpful Books:
  - Python for Data Analysis, W. McKinney
  - Effective Pandas, M. Harrison
  - Intro to Python, Deitel & Deitel
  - Python Data Science Handbook, J. VanderPlas
- Research papers
- Many websites

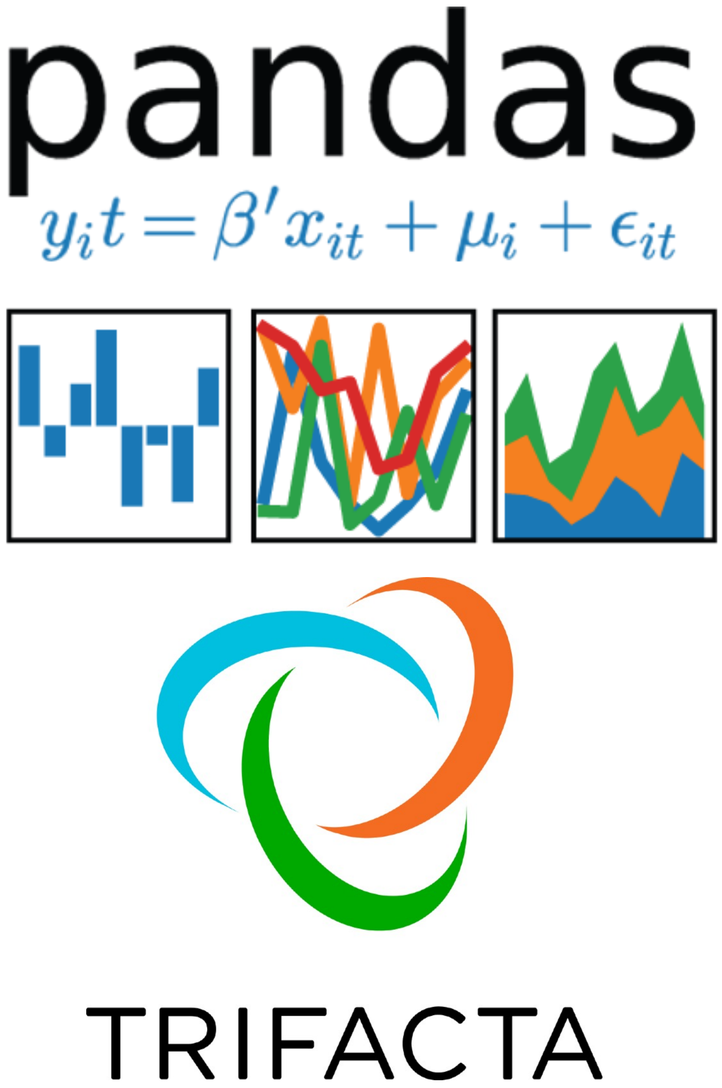


Course Material

- Software:
  - Anaconda Python Distribution (https://www.anaconda.com/distribution/): makes installing python and python packages easier
  - JupyterLab: Web-based interface for interactively writing and executing Python code
  - JupyterHub: Access everything through a server

Course Material

- Pandas:
  - Python library for data analysis
  - Many operations available
  - Efficient
- DuckDB
- Ibis
- Trifacta Wrangler
- More…



Office Hours & Email

- Scheduled office hours:
  - M: 2-3:15pm, W: 1-2:15pm, or by appointment
- You do not need an appointment to stop in during scheduled office hours
- If you need an appointment outside of those times, please email me with **specific details** about what you wish to discuss
- Many questions can be answered via email. Please **do not** schedule an appointment to ask a question that could be answered via email

Next Class

- Introduction to/review of Python
- Download and install anaconda distribution (Python 3.10):
  - https://www.anaconda.com/distribution/