Introduction to Big Data Visualization

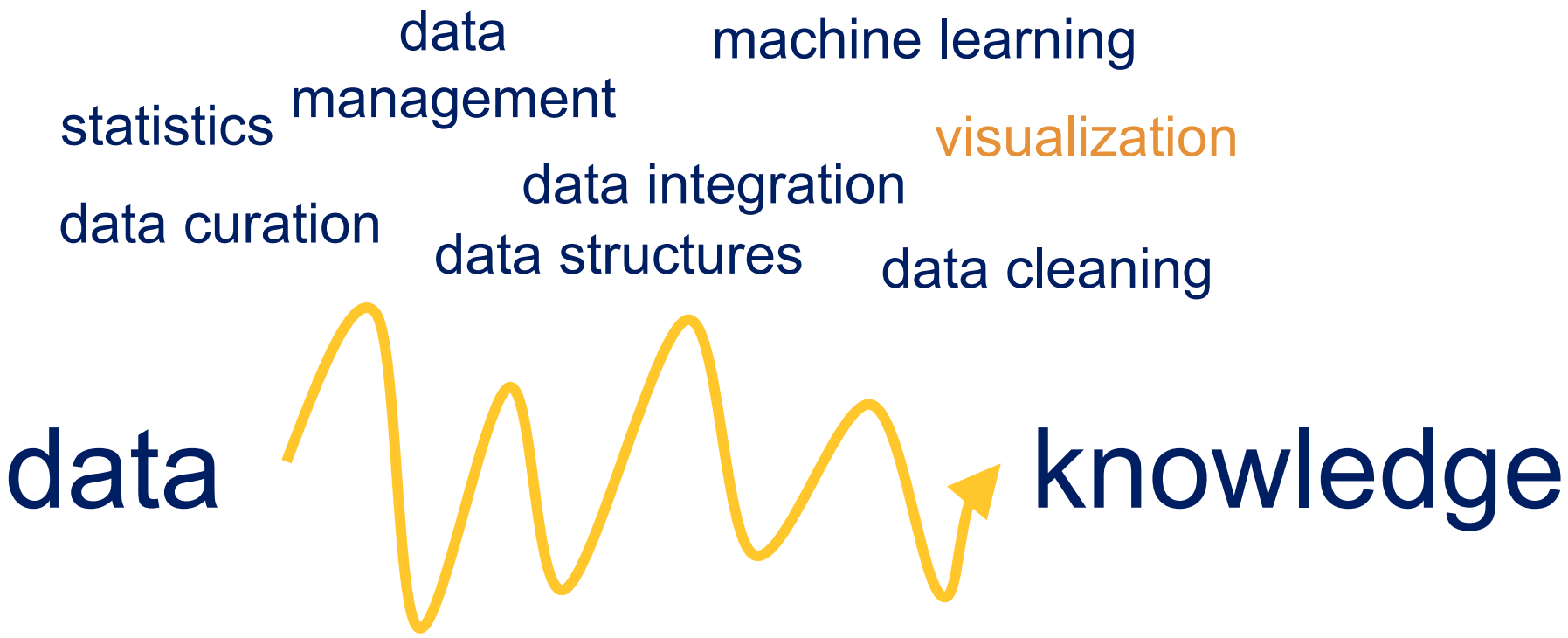
CS594: Big Data Visualization & Analytics

Fabio Miranda

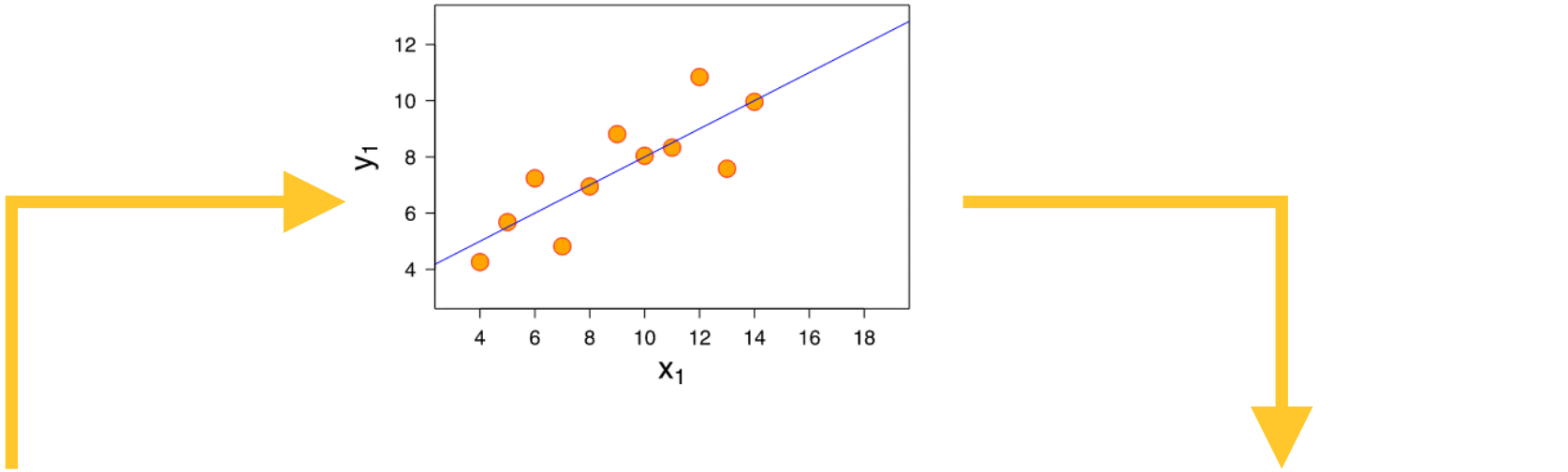
https://fmiranda.me

Data to knowledge

Data to knowledge



Data to knowledge



Transform data into visual marks

What is data visualization?

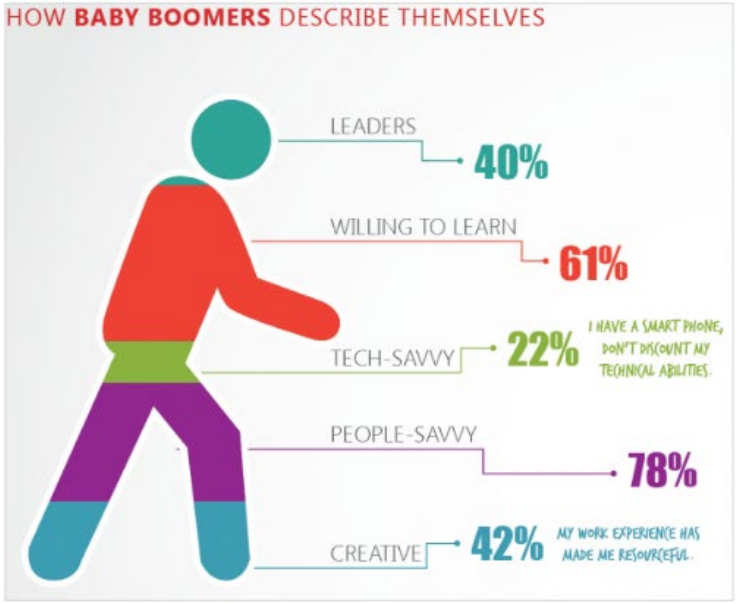
"*Data visualization is the graphical representation of information and data. By using visual elements like charts, graphs, and maps, data visualization tools provide an accessible way to see and understand trends, outliers, and patterns in data*."

Tableau

Data visualization

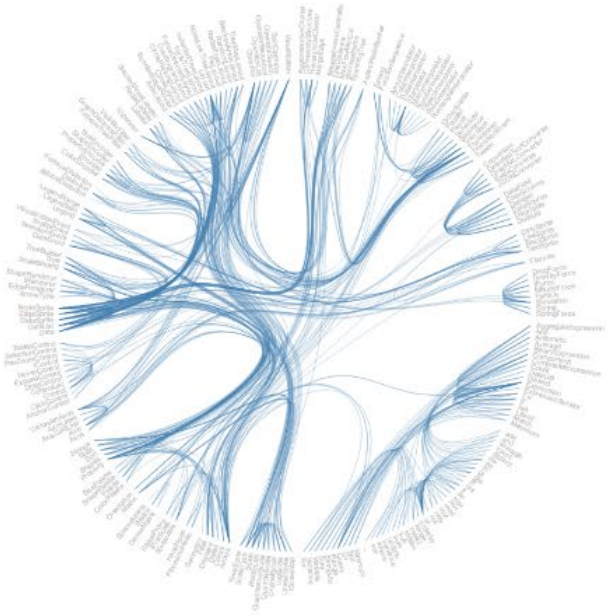
Data visualization

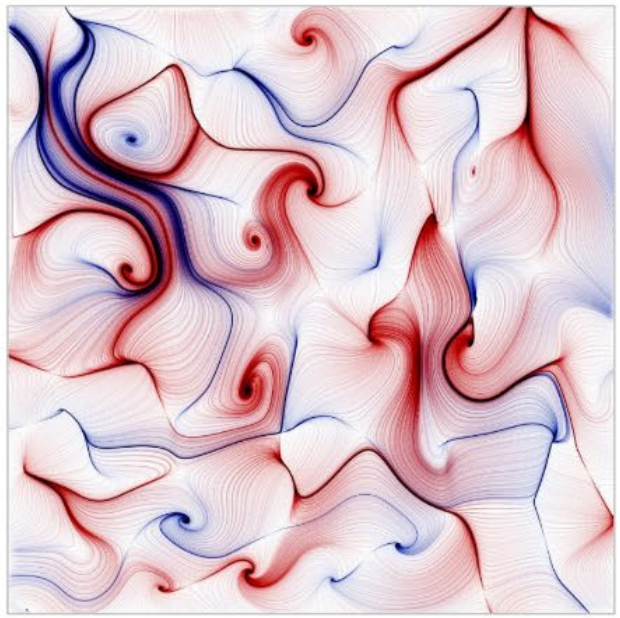
insight → Communication → insight

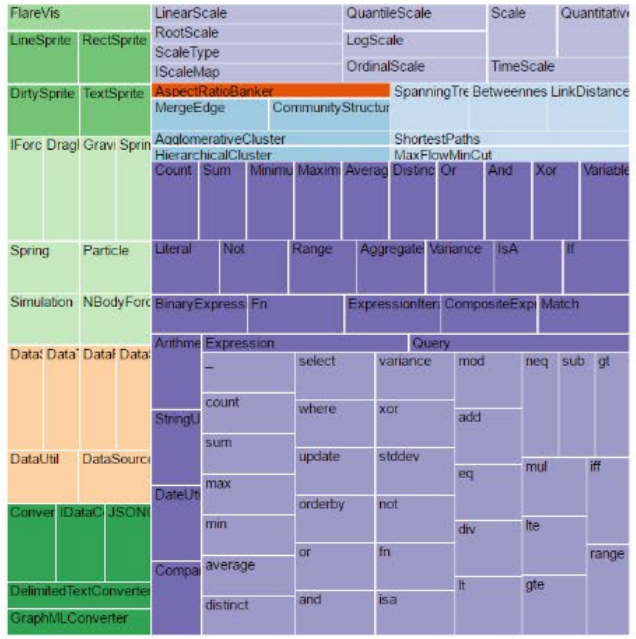


Data visualization

data → Exploration / Analysis → insight



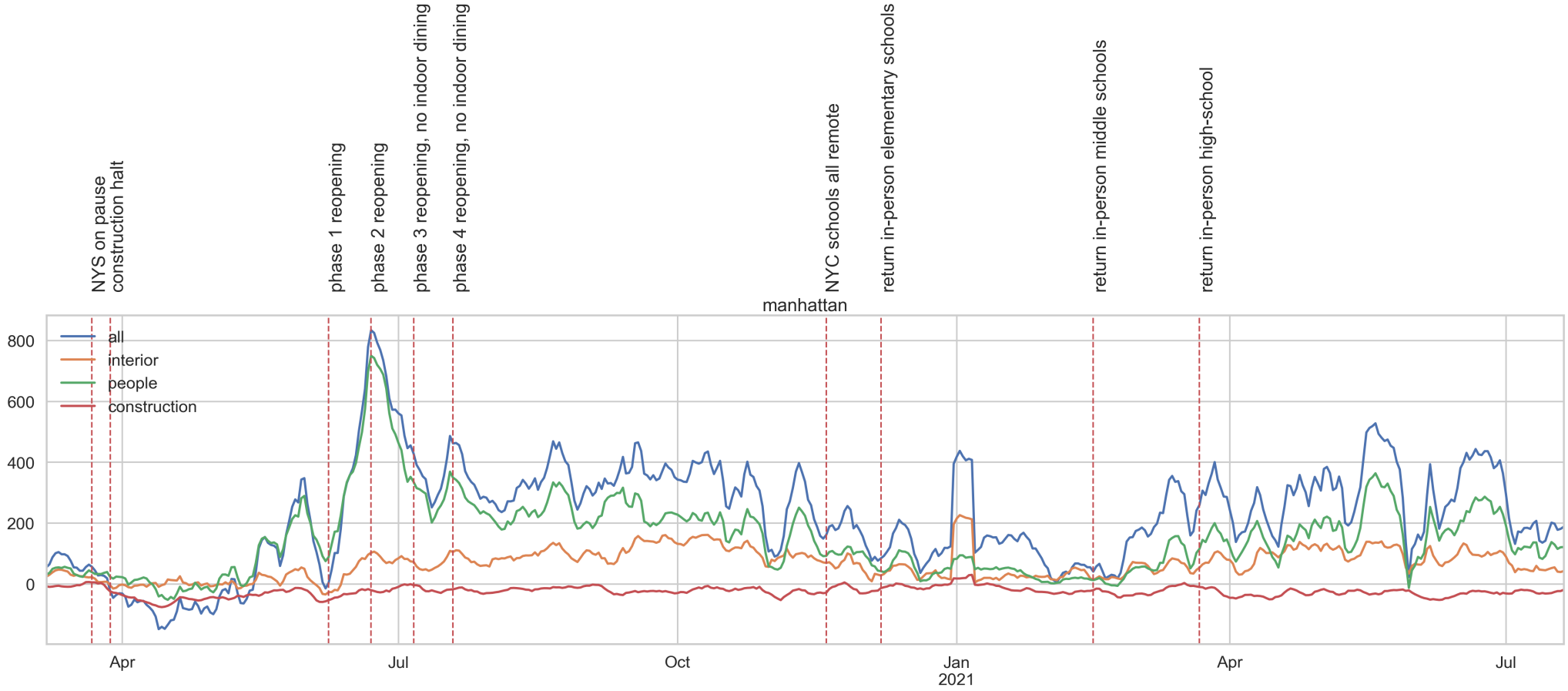




Example:
Noise complaints during pandemic

	date	unique_key	created_date	closed_date	agency	agency_name	complaint_type	descriptor	location_type	incident_zip	...	landmark	date.1	hour_of_day	week	weekday	year	day_of_month	month	aligned_day_index	datetime
0	2017-01-01	35138317	2017-01-01T00:02:54.000	2017-01-01T00:46:54.000	NYPD	New York City Police Department	Noise - Residential	Loud Music/Party	Residential Building/House	11209.0	...	NaN	2017-01-01 00:02:54	0	52	6	2017	1	1	0.0	2017-01-01 00:02:54
1	2017-01-01	35139300	2017-01-01T00:03:41.000	2017-01-01T03:49:13.000	NYPD	New York City Police Department	Noise - Residential	Loud Music/Party	Residential Building/House	10040.0	...	NaN	2017-01-01 00:03:41	0	52	6	2017	1	1	0.0	2017-01-01 00:03:41
2	2017-01-01	35137537	2017-01-01T00:04:01.000	2017-01-01T00:44:40.000	NYPD	New York City Police Department	Noise - Residential	Banging/Pounding	Residential Building/House	11214.0	...	NaN	2017-01-01 00:04:01	0	52	6	2017	1	1	0.0	2017-01-01 00:04:01
3	2017-01-01	35138401	2017-01-01T00:06:04.000	2017-01-01T01:52:03.000	NYPD	New York City Police Department	Noise - Residential	Loud Music/Party	Residential Building/House	11691.0	...	NaN	2017-01-01 00:06:04	0	52	6	2017	1	1	0.0	2017-01-01 00:06:04
4	2017-01-01	35139201	2017-01-01T00:08:24.000	2017-01-01T06:43:42.000	NYPD	New York City Police Department	Noise - Residential	Loud Music/Party	Residential Building/House	10458.0	...	NaN	2017-01-01 00:08:24	0	52	6	2017	1	1	0.0	2017-01-01 00:08:24
5	2017-01-01	35140227	2017-01-01T00:09:08.000	2017-01-01T02:16:21.000	NYPD	New York City Police Department	Noise - Residential	Loud Television	Residential Building/House	11366.0	...	NaN	2017-01-01 00:09:08	0	52	6	2017	1	1	0.0	2017-01-01 00:09:08
6	2017-01-01	35138514	2017-01-01T00:09:22.000	2017-01-01T01:27:35.000	NYPD	New York City Police Department	Noise - Commercial	Loud Music/Party	Club/Bar /Restaurant	11217.0	...	NaN	2017-01-01 00:09:22	0	52	6	2017	1	1	0.0	2017-01-01 00:09:22
7	2017-01-01	35141927	2017-01-01T00:12:02.000	2017-01-01T00:59:53.000	NYPD	New York City Police Department	Noise - Residential	Loud Music/Party	Residential Building/House	11204.0	...	NaN	2017-01-01 00:12:02	0	52	6	2017	1	1	0.0	2017-01-01 00:12:02
8	2017-01-01	35138731	2017-01-01T00:12:36.000	2017-01-01T08:29:48.000	NYPD	New York City Police Department	Noise - Residential	Loud Music/Party	Residential Building/House	10457.0	...	NaN	2017-01-01 00:12:36	0	52	6	2017	1	1	0.0	2017-01-01 00:12:36
9	2017-01-01	35141039	2017-01-01T00:12:44.000	2017-01-01T00:45:47.000	NYPD	New York City Police Department	Noise - Residential	Loud Music/Party	Residential Building/House	10312.0	...	NaN	2017-01-01 00:12:44	0	52	6	2017	1	1	0.0	2017-01-01 00:12:44

Example:
Noise complaints during pandemic



Why visualization?

- Our brains are wired in a visual way.
- Help analysts avoid problems.
- Better communicate findings.
- "*Visualization gives you answer to questions you didn't know you had.*"

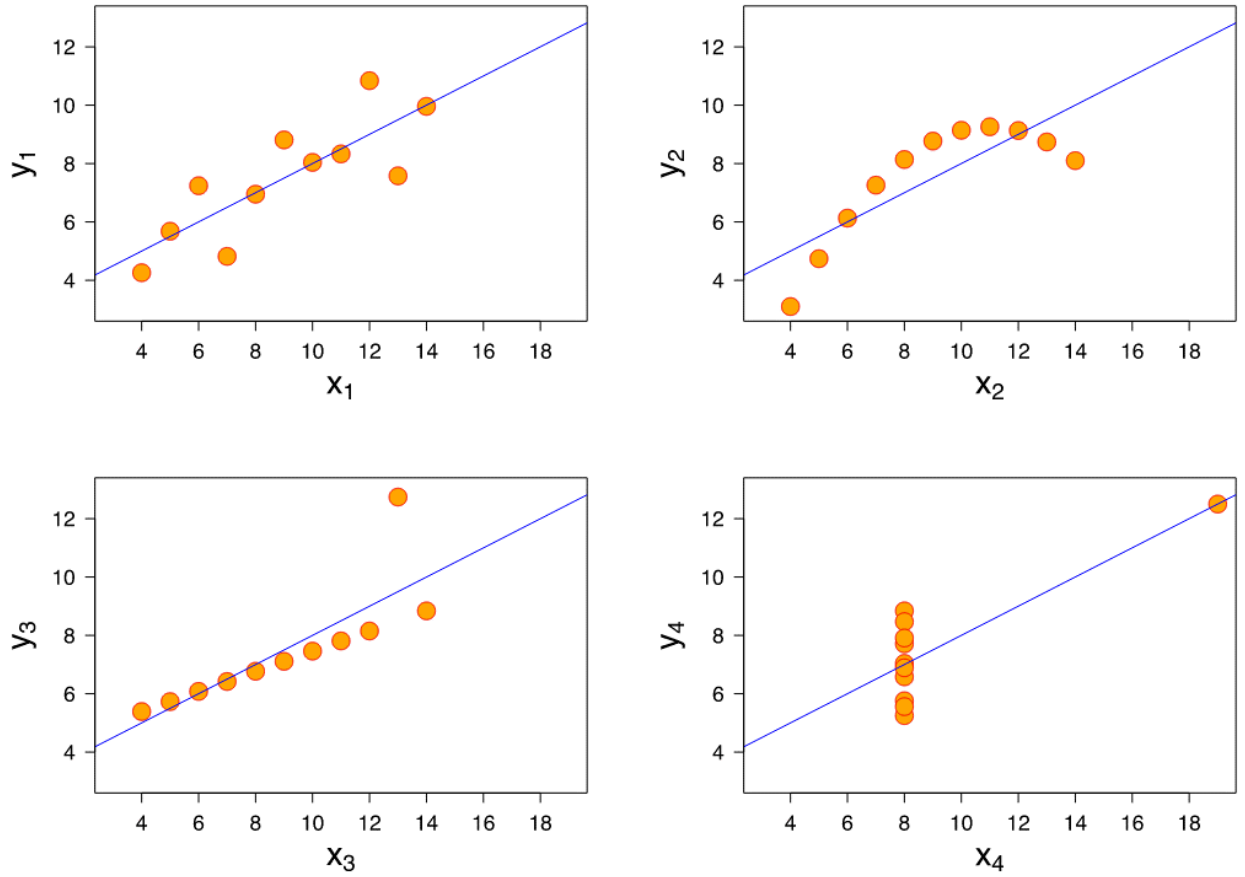
Ben Schneiderman

Importance of visualization

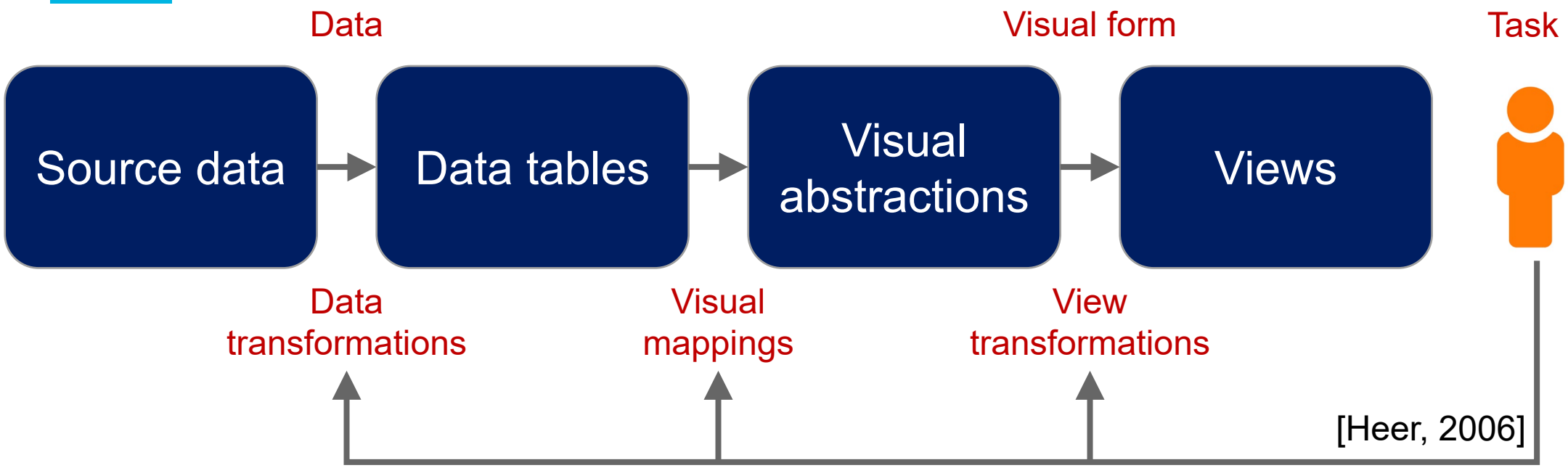
A		B		C		D	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

Property	A	B	C	D
Mean of x	9	9	9	9
Mean of y	7.5	7.5	7.5	7.5
Std of x	3.32	3.32	3.32	3.32
Std of y	2.03	2.03	2.03	2.03

Importance of visualization

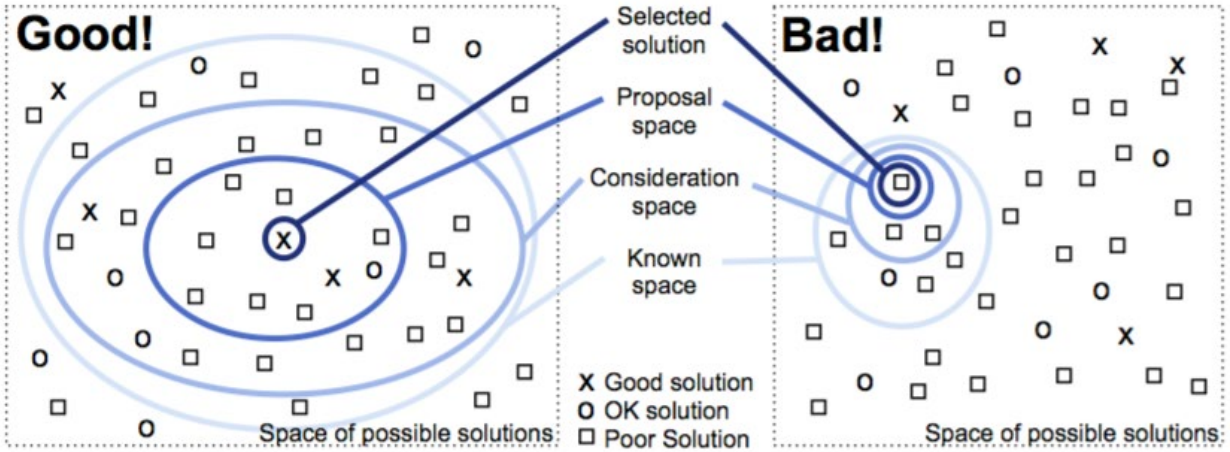


Visualization design



- Creating a data visualization is easy; creating a **good** visualization is hard.
- Visualization design space is huge, it's important to make good choices in each stage.

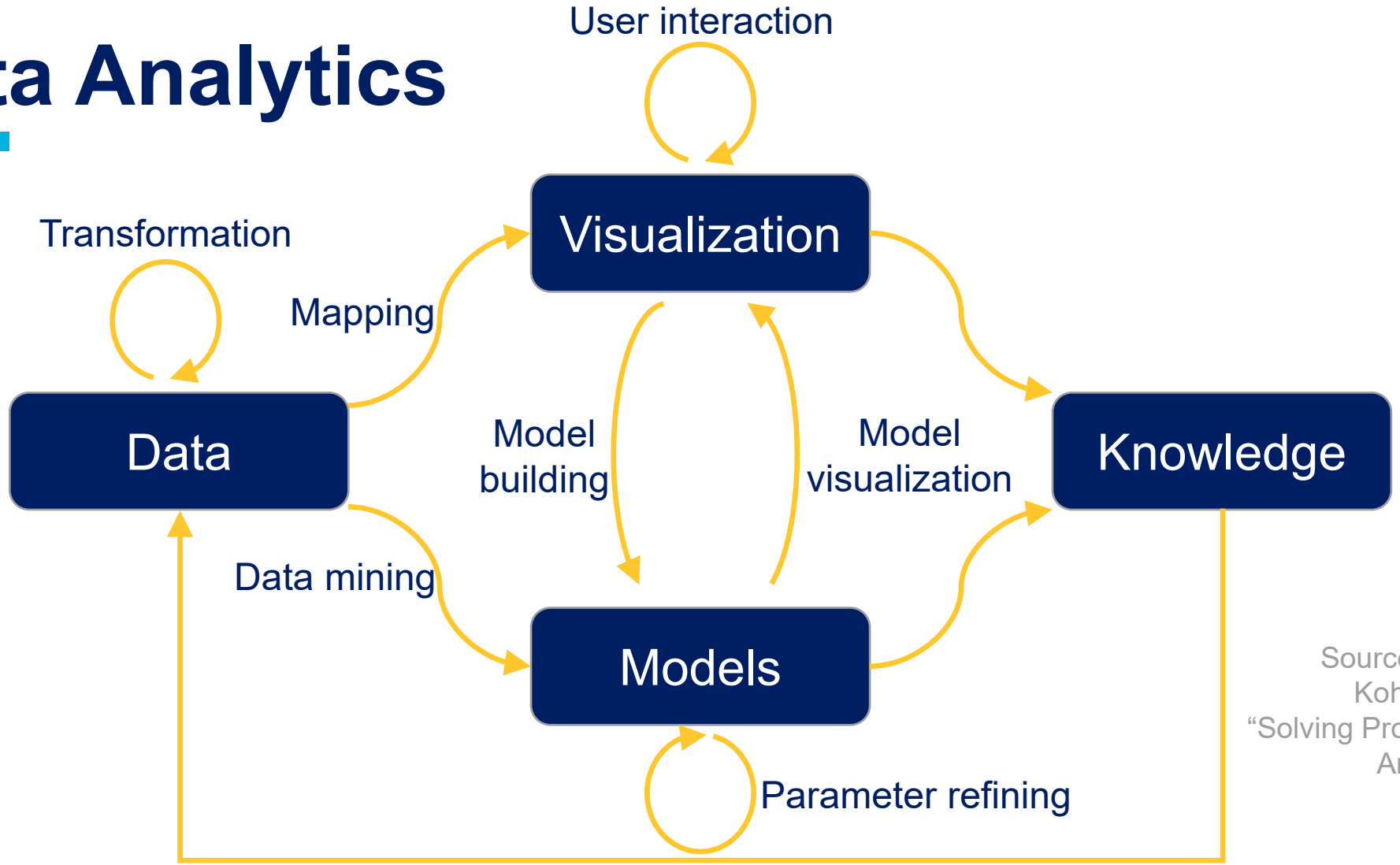
Visualization design



[Munzner, 2015]

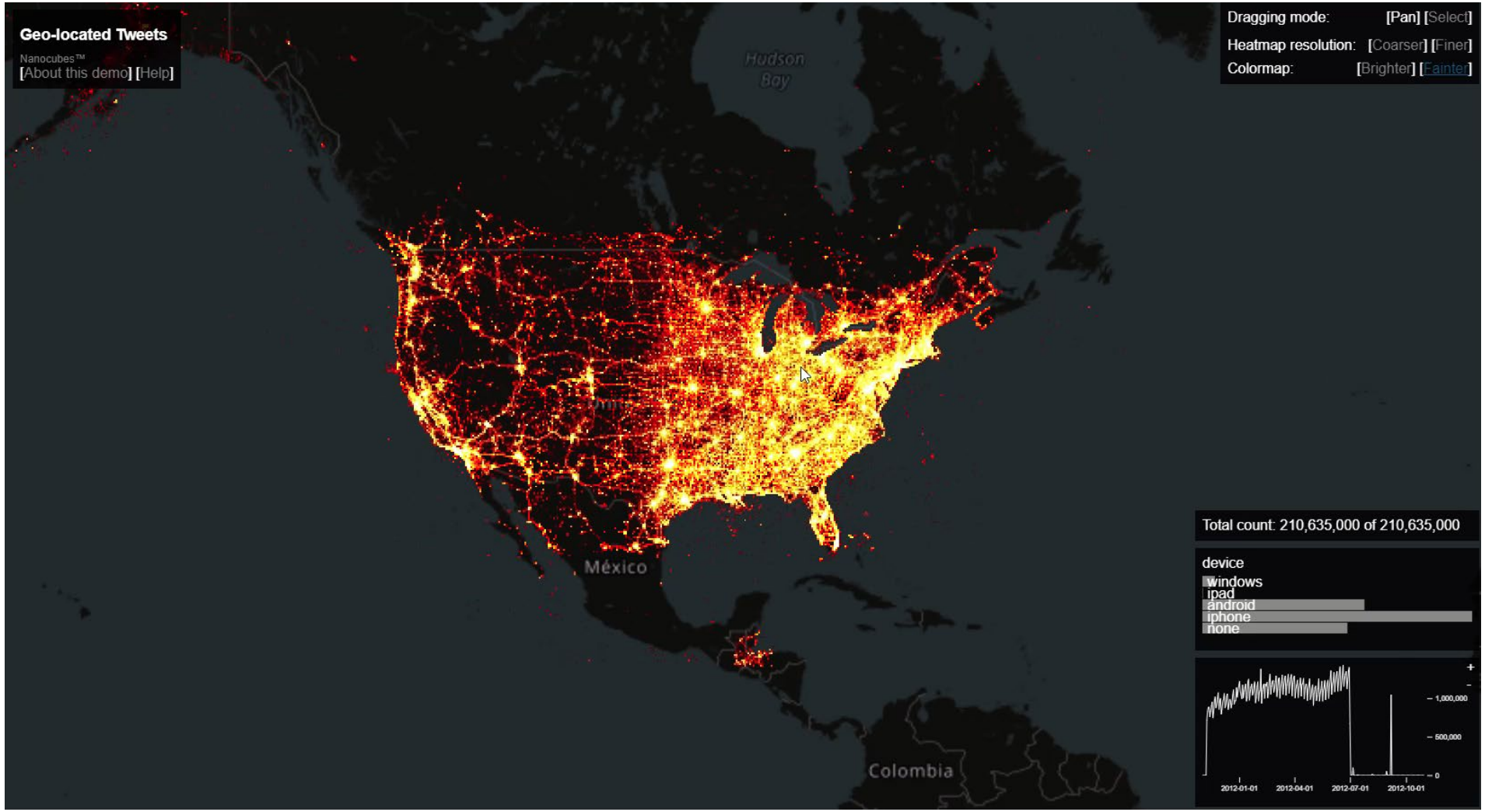
Develop principles and techniques to build effective visualizations.

Data Analytics

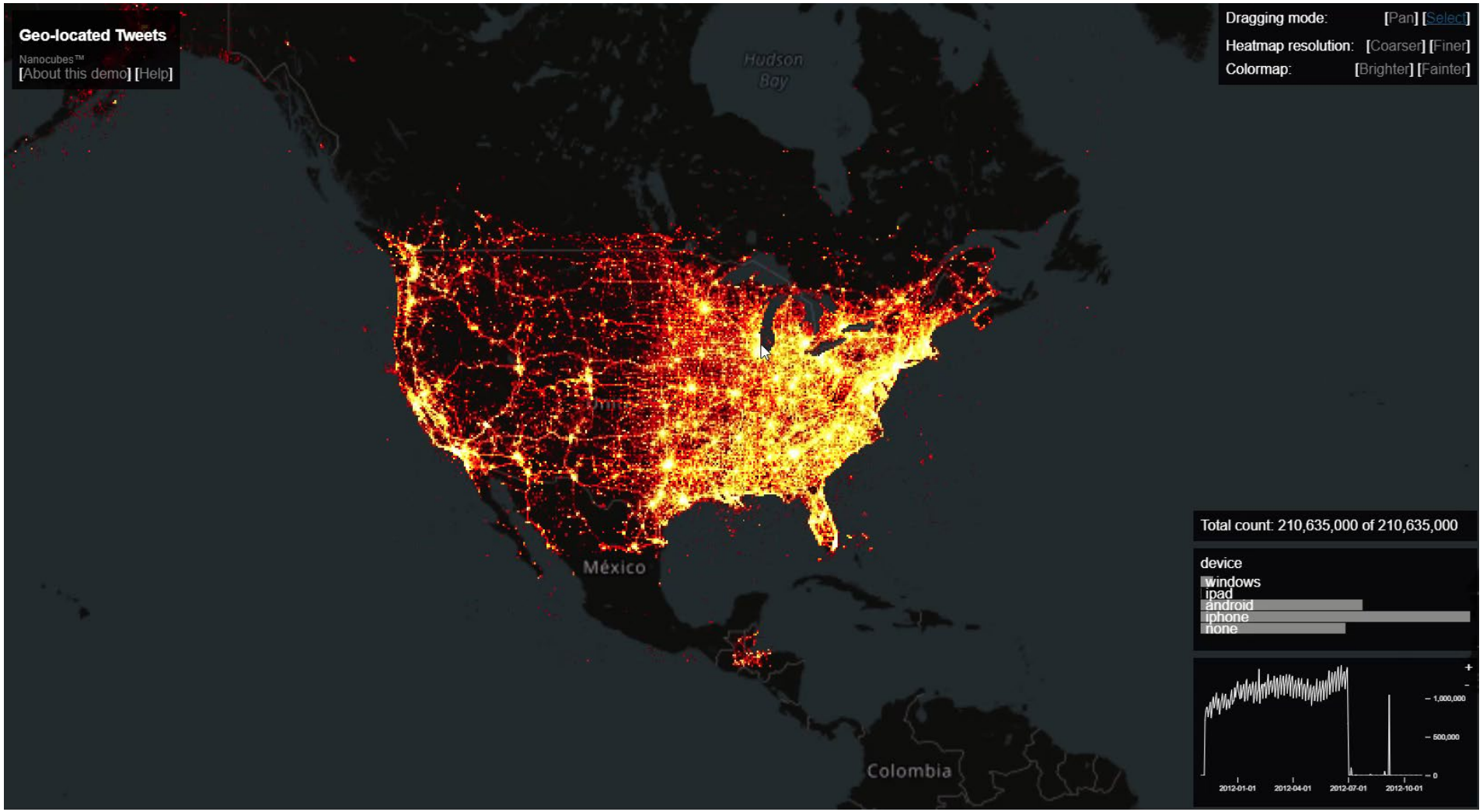


Source: Kleim and Kohlhammer, "Solving Problems with Visual Analytics"

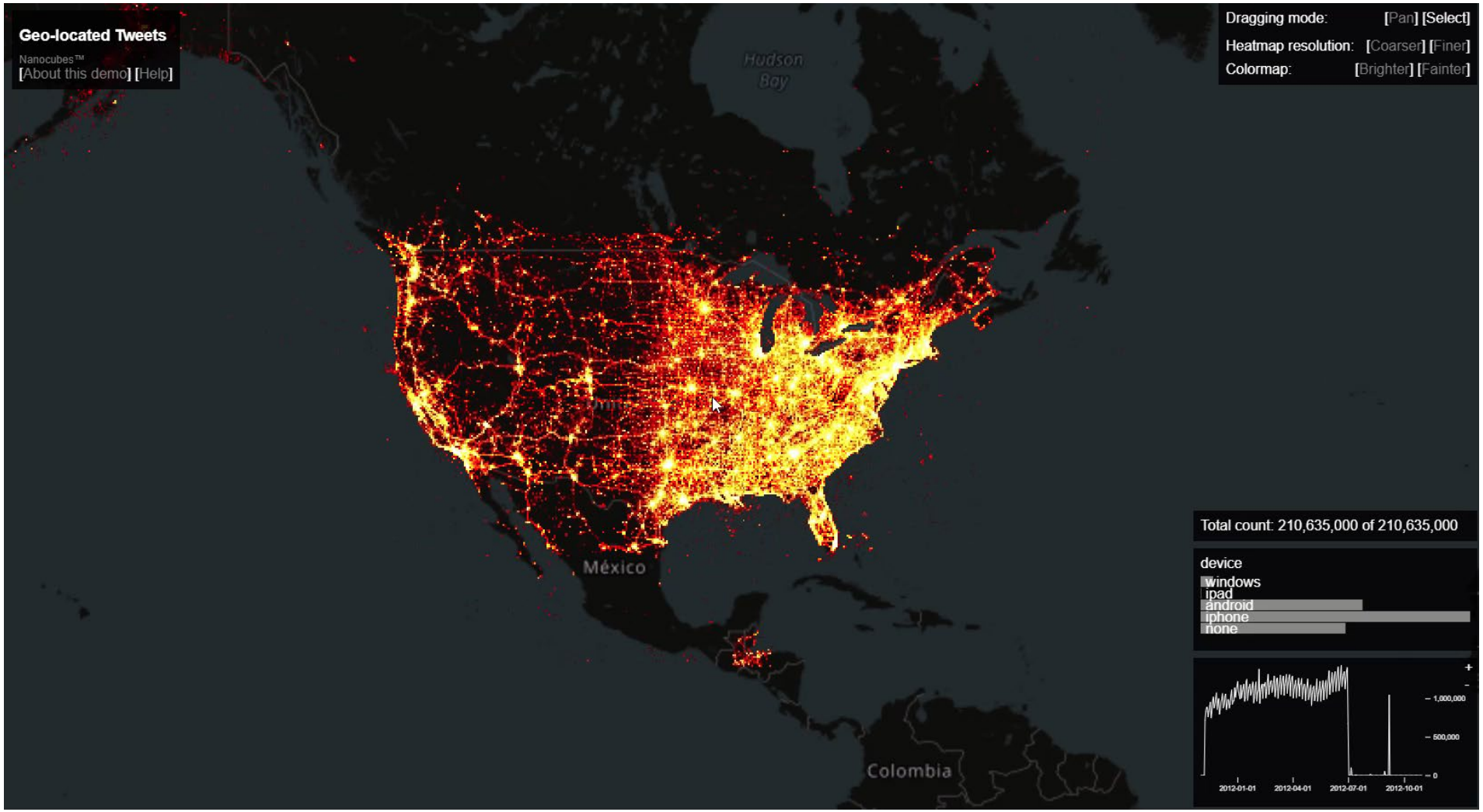
Visualization requirements: brushing & linking



Visualization requirements: spatial brushing & linking



Visualization requirements: panning and zooming



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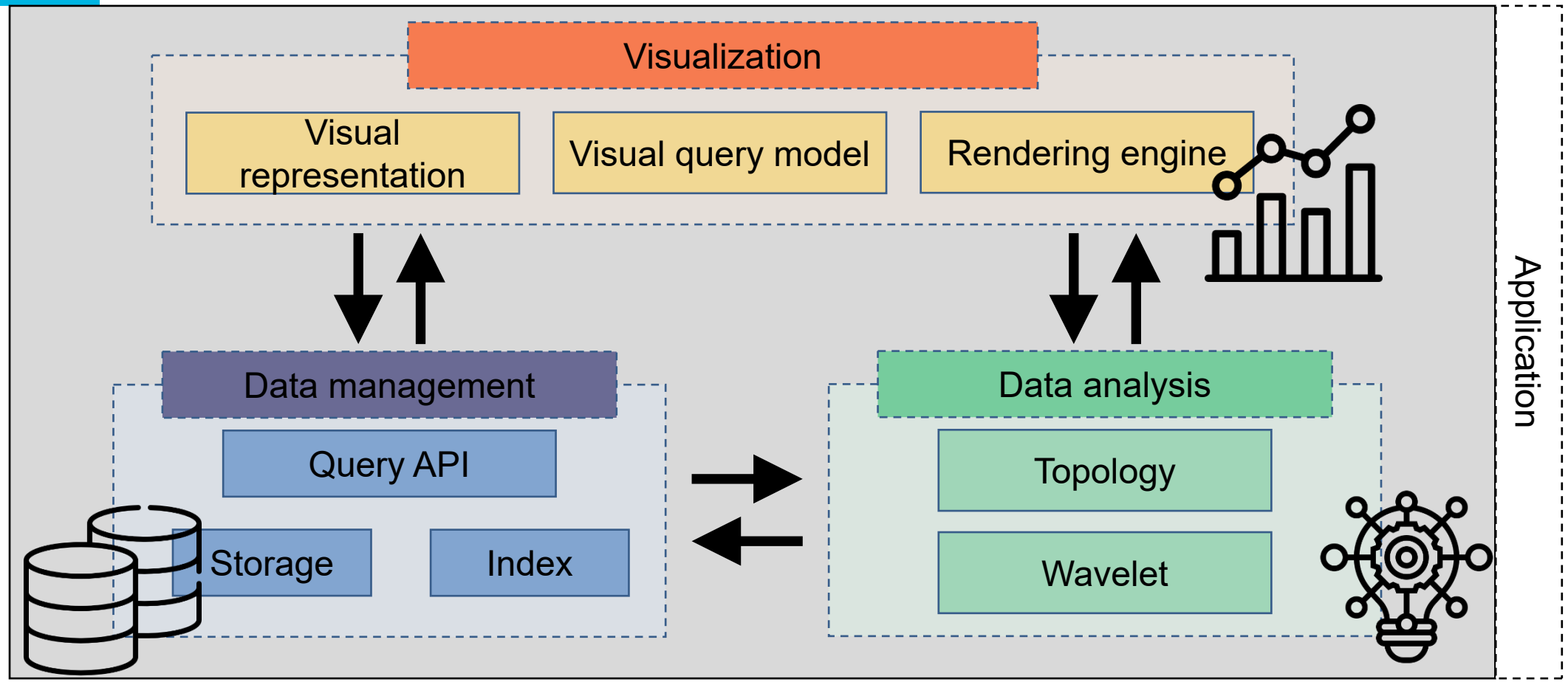
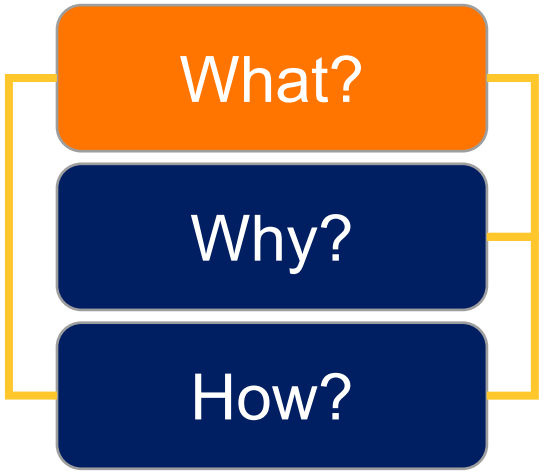


Visualization design

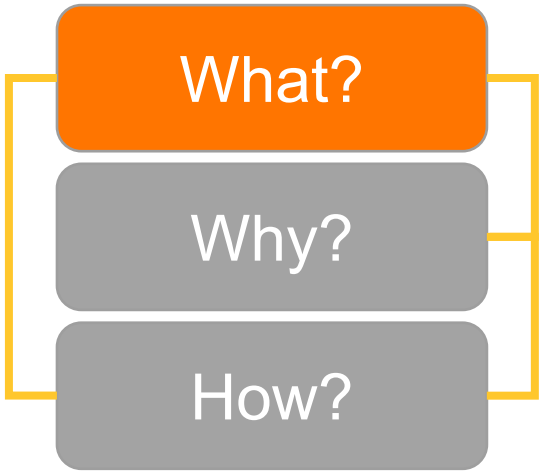
- High-level framework for analyzing vis use:
  - **What** data user sees?
  - **Why** the user intends to use a vis tool?
  - **How** the user intends to use a vis tool?



[Munzner, 2015]

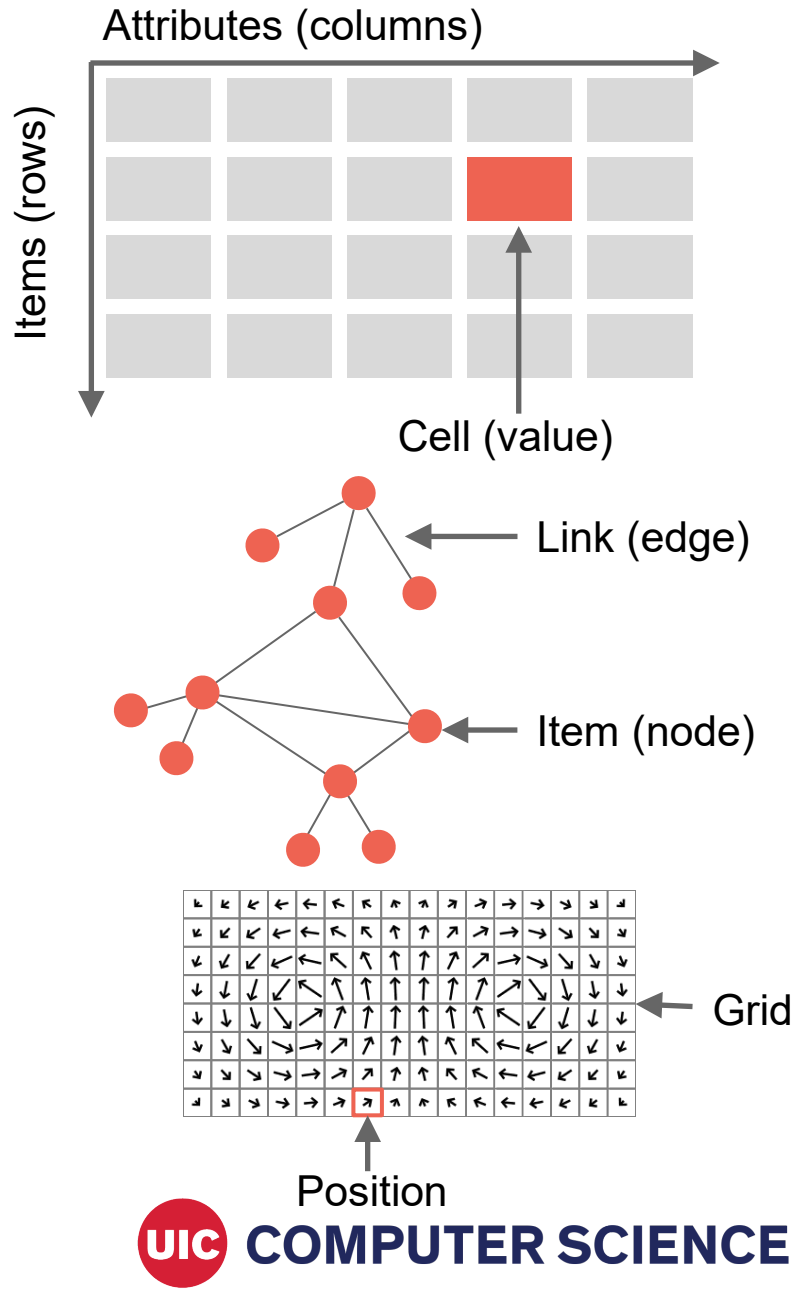
Principles of visualization

- Data
- Visual marks
- Visual channels
- Interaction



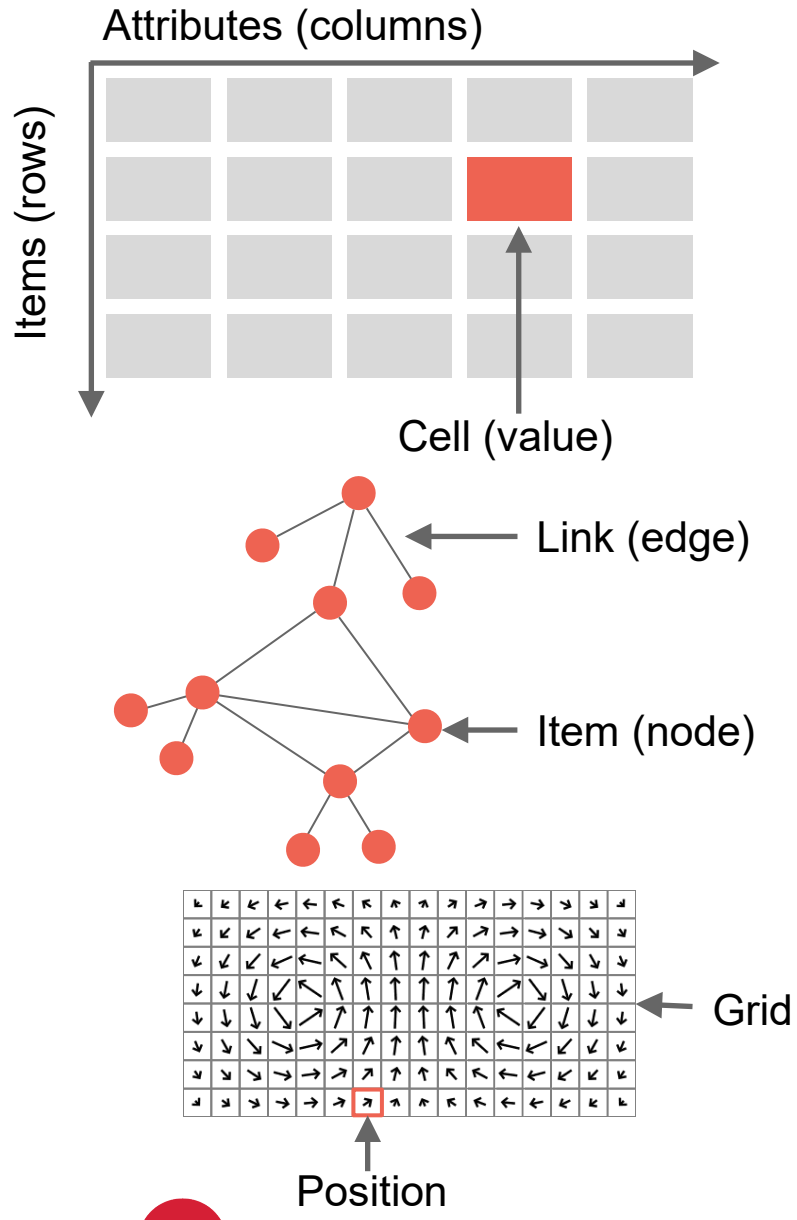
Data types

- Items: individual, discrete entity – record, data point, etc.
- Attributes: item property that can be measured, observed, logged.
- Links: relationship between entities.
- Position: spatial location.
- Grids: strategy for sampling continuous data.



Dataset types

- Table: items and attributes
- Networks & trees: items (nodes), links, attributes
- Fields: grids, positions, attributes.
- Clusters, sets, lists: items.



Attribute types

- Categorical: attributes draw from a discrete set, but there may exist hierarchical structure.
  - Fruits, vegetables, furniture type, car type, …
- Ordered: attributes with a natural *ordering*.
  - Ordinal: well-defined ordering, but we cannot do mathematical operations.
    - T-Shirt size (large, medium, small), ranks.
  - Quantitative: measurement of magnitude that supports comparison / mathematical operations.
    - Height, temperature, density, …

Attribute types

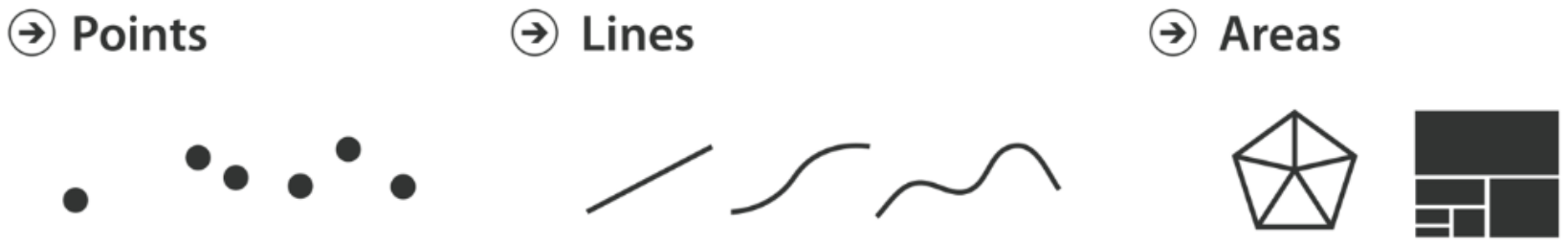
- Ordered: different ordering directions.
  - Sequential: homogeneous range from minimum to maximum value.

  - Diverging: can be deconstructed into two sequences pointing in opposite directions that meet at a common zero point.

  - Cyclic: values wrap around back to starting point.

Visual marks

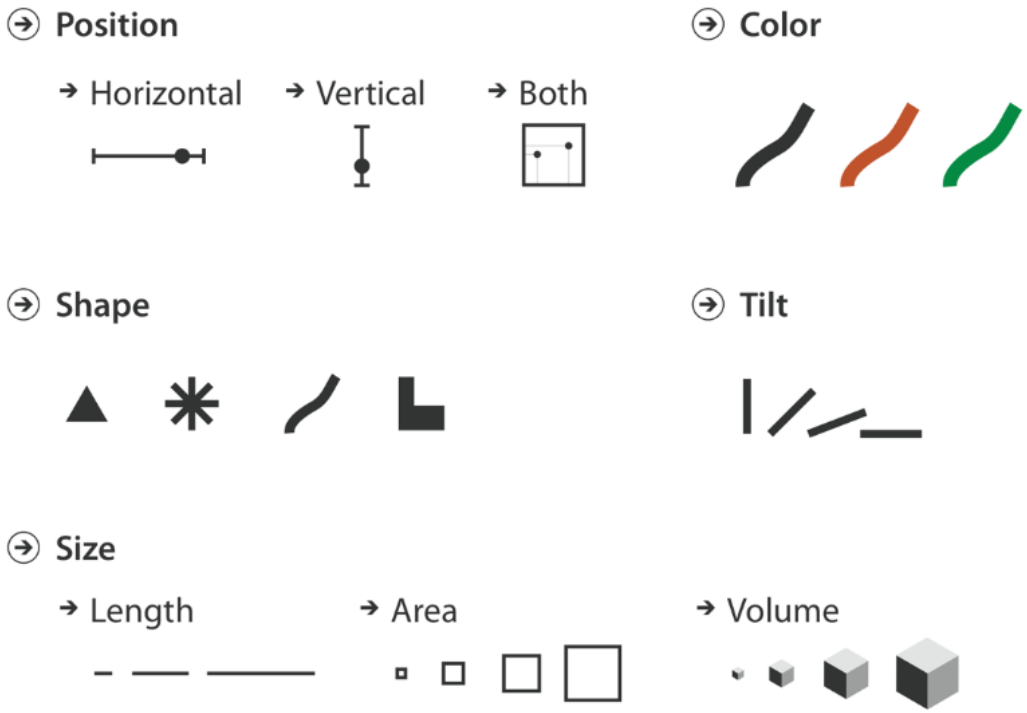
- Represent items and links.
- Geometric primitives, can be classified according to their spatial dimensions: 0D (points), 1D (lines), 2D (areas), etc.



[Munzner, 2014]

Visual channels

- Encode properties of a mark.
- Control appearance based on data attributes.



[Munzner, 2014]

Visual marks & channels

- We can associate tabular data with visual marks and channels as follows:

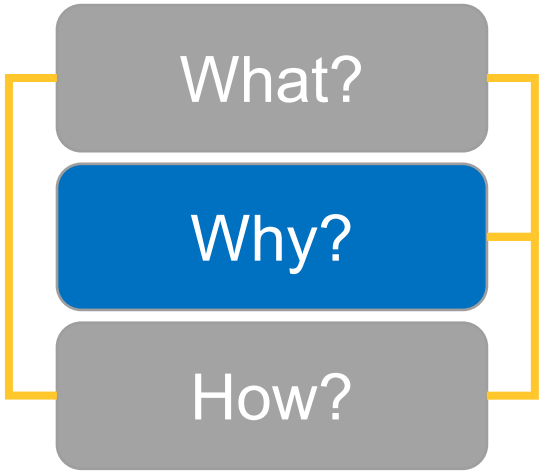
Attributes → Channels

Items ↓ Marks

Car	Horsepower	Year	Color
Car 1	60	2013	Silver
Car 2	86	2015	Green
Car 3	55	1999	Red
Car 4	50	1990	Blue

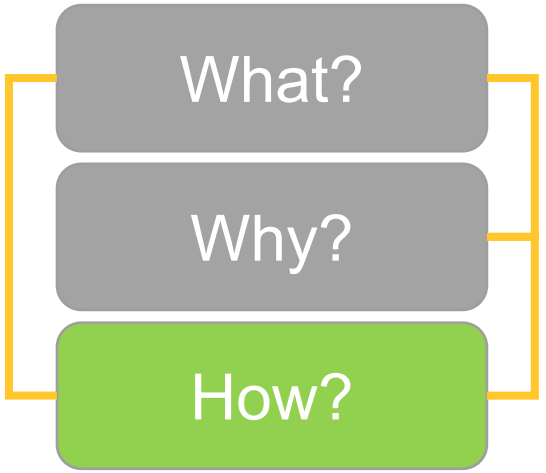
Task abstraction

- Analyzing tasks abstractly – rather than thinking of domain-specific tasks, think of abstract tasks.
- Domain-specific task: “contrast the prognosis of patients who were intubated in the ICU more than one month to patients hospitalized within the first week.”
- Abstract tasks: “compare values between two groups.”



How to design vis idioms

- How a vis idiom can be constructed out of a set of design choices?
  - Encode
  - Manipulate: change, select, navigate
  - Facet: coordinate multiple views
  - Reduce: filter, aggregate



Big data example

Distribution of NYC Taxi Pickups and Dropoffs in Midtown Manhattan

Big data example

VendorID	tpep_pickup_datetime	tpep_dropoff_datetime	passenger_count	trip_distance	RatecodeID	store_and_f	PULocationID	DOLocationID	payment_	fare_amo	extra	mta_tax	tip_amou	tolls_amo	improvem	total_amount
1	1/1/2018 0:21	1/1/2018 0:24	1	0.5	1	N	41	24	2	4.5	0.5	0.5	0	0	0.3	5.8
1	1/1/2018 0:44	1/1/2018 1:03	1	2.7	1	N	239	140	2	14	0.5	0.5	0	0	0.3	15.3
1	1/1/2018 0:08	1/1/2018 0:14	2	0.8	1	N	262	141	1	6	0.5	0.5	1	0	0.3	8.3
1	1/1/2018 0:20	1/1/2018 0:52	1	10.2	1	N	140	257	2	33.5	0.5	0.5	0	0	0.3	34.8
1	1/1/2018 0:09	1/1/2018 0:27	2	2.5	1	N	246	239	1	12.5	0.5	0.5	2.75	0	0.3	16.55
1	1/1/2018 0:29	1/1/2018 0:32	3	0.5	1	N	143	143	2	4.5	0.5	0.5	0	0	0.3	5.8
1	1/1/2018 0:38	1/1/2018 0:48	2	1.7	1	N	50	239	1	9	0.5	0.5	2.05	0	0.3	12.35
1	1/1/2018 0:49	1/1/2018 0:51	1	0.7	1	N	239	238	1	4	0.5	0.5	1	0	0.3	6.3
1	1/1/2018 0:56	1/1/2018 1:01	1	1	1	N	238	24	1	5.5	0.5	0.5	1.7	0	0.3	8.5
1	1/1/2018 0:17	1/1/2018 0:22	1	0.7	1	N	170	170	2	5.5	0.5	0.5	0	0	0.3	6.8
1	1/1/2018 0:41	1/1/2018 0:46	1	0.6	1	N	162	229	1	5.5	0.5	0.5	1.35	0	0.3	8.15

Data transformation

- Filter the data:
  - Only rows within Manhattan.
  - Only rows inside certain blocks of Manhattan.
- Merge data with other data:
  - Traffic accidents within 100 meters and 1 hour of pickup and dropoff.
- Aggregate the data:
  - Number of pickups in each hour.
  - Number of pickups in each day of the week..

Data transformation

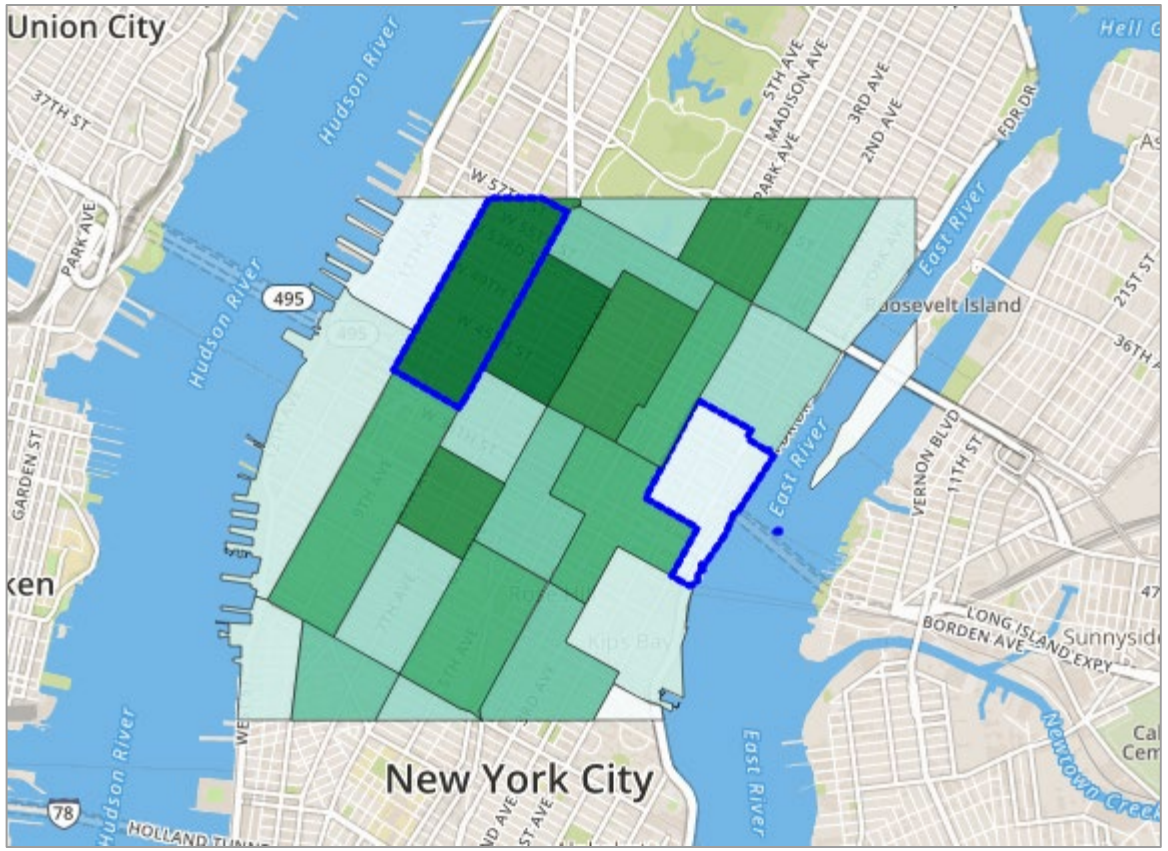
VendorID	tpep_pickup_datetime	tpep_dropoff_datetime	passenger_count	trip_distance	RatecodeID	store_and_f	PULocationID	DOLocationI	payment_	fare_amo	extra	mta_tax	tip_amou	tolls_amo	improven	total_amount
1	1/1/2018 0:21	1/1/2018 0:24	1	0.5	1	N	41	24	2	4.5	0.5	0.5	0	0	0.3	5.8
1	1/1/2018 0:44	1/1/2018 1:03	1	2.7	1	N	239	140	2	14	0.5	0.5	0	0	0.3	15.3
1	1/1/2018 0:08	1/1/2018 0:14	2	0.8	1	N	262	141	1	6	0.5	0.5	1	0	0.3	8.3
1	1/1/2018 0:20	1/1/2018 0:52	1	10.2	1	N	140	257	2	33.5	0.5	0.5	0	0	0.3	34.8
1	1/1/2018 0:09	1/1/2018 0:27	2	2.5	1	N	246	239	1	12.5	0.5	0.5	2.75	0	0.3	16.55
1	1/1/2018 0:29	1/1/2018 0:32	3	0.5	1	N	143	143	2	4.5	0.5	0.5	0	0	0.3	5.8
1	1/1/2018 0:38	1/1/2018 0:48	2	1.7	1	N	50	239	1	9	0.5	0.5	2.05	0	0.3	12.35
1	1/1/2018 0:49	1/1/2018 0:51	1	0.7	1	N	239	238	1	4	0.5	0.5	1	0	0.3	6.3
1	1/1/2018 0:56	1/1/2018 1:01	1	1	1	N	238	24	1	5.5	0.5	0.5	1.7	0	0.3	8.5
1	1/1/2018 0:17	1/1/2018 0:22	1	0.7	1	N	170	170	2	5.5	0.5	0.5	0	0	0.3	6.8
1	1/1/2018 0:41	1/1/2018 0:46	1	0.6	1	N	162	229	1	5.5	0.5	0.5	1.35	0	0.3	8.15
1	1/1/2018 0:52	1/1/2018 1:17	1	3.5	1	N	141	113	2	16.5	0.5	0.5	0	0	0.3	17.8
2	1/1/2018 0:17	1/1/2018 0:22	1	1.04	1	N	137	224	2	5.5	0.5	0.5	0	0	0.3	6.8
2	1/1/2018 0:24	1/1/2018 0:34	1	1.22	1	N	224	79	2	7.5	0.5	0.5	0	0	0.3	8.8
2	1/1/2018 0:37	1/1/2018 0:53	1	1.92	1	N	234	100	2	10	0.5	0.5	0	0	0.3	11.3
1	1/1/2018 0:35	1/1/2018 0:52	1	5.7	1	N	13	189	1	19	0.5	0.5	4.05	0	0.3	24.35
2	1/1/2018 0:30	1/1/2018 1:13	1	3.74	1	N	48	236	1	25.5	0.5	0.5	6.7	0	0.3	33.5
1	1/1/2018 0:21	1/1/2018 0:25	2	0.6	1	N	163	162	1	4.5	0.5	0.5	1.7	0	0.3	7.5
1	1/1/2018 0:31	1/1/2018 1:07	1	10.9	1	N	229	61	2	35	0.5	0.5	0	0	0.3	36.3
2	1/1/2018 0:15	1/1/2018 0:21	5	1.22	1	N	236	75	2	6	0.5	0.5	0	0	0.3	7.3
2	1/1/2018 0:25	1/1/2018 0:45	5	3.13	1	N	263	143	2	13	0.5	0.5	0	0	0.3	14.3
2	1/1/2018 0:51	1/1/2018 1:04	5	2.22	1	N	239	24	2	9.5	0.5	0.5	0	0	0.3	10.8
2	1/1/2018 0:09	1/1/2018 0:30	1	2.93	1	N	90	233	1	14.5	0.5	0.5	2	0	0.3	17.8
2	1/1/2018 0:32	1/1/2018 0:58	1	3.52	1	N	233	125	2	18	0.5	0.5	0	0	0.3	19.3
1	1/1/2018 0:41	1/1/2018 0:54	4	3	1	N	161	146	1	12	0.5	0.5	2.65	0	0.3	15.95
2	1/1/2018 0:17	1/1/2018 0:21	5	0.25	1	N	234	234	2	4.5	0.5	0.5	0	0	0.3	5.8
2	1/1/2018 0:24	1/1/2018 0:46	5	3.31	1	N	234	143	1	16	0.5	0.5	3.46	0	0.3	20.76
2	1/1/2018 0:48	1/1/2018 0:51	5	0.57	1	N	142	239	1	4	0.5	0.5	1.06	0	0.3	6.36
1	1/1/2018 0:24	1/1/2018 0:31	2	0.7	1	N	170	162	2	6	0.5	0.5	0	0	0.3	7.3
1	1/1/2018 0:36	1/1/2018 0:43	1	1.8	1	N	233	263	2	7.5	0.5	0.5	0	0	0.3	8.8
1	1/1/2018 0:49	1/1/2018 0:57	2	1.2	1	N	236	237	2	7.5	0.5	0.5	0	0	0.3	8.8
1	1/1/2018 0:13	1/1/2018 0:23	1	2.7	1	N	142	166	1	10.5	0.5	0.5	2.35	0	0.3	14.15
1	1/1/2018 0:33	1/1/2018 1:18	2	4.3	1	N	238	249	2	27.5	0.5	0.5	0	0	0.3	28.8
2	1/1/2018 0:15	1/1/2018 0:22	1	0.89	1	N	151	238	2	5.5	0.5	0.5	0	0	0.3	6.8
2	1/1/2018 0:25	1/1/2018 0:29	1	0.49	1	N	238	238	1	4.5	0.5	0.5	1.45	0	0.3	7.25
2	1/1/2018 0:32	1/1/2018 0:36	2	0.8	1	N	238	151	1	5	0.5	0.5	1.26	0	0.3	7.56
2	1/1/2018 0:45	1/1/2018 0:58	1	2.09	1	N	238	143	1	11	0.5	0.5	2.46	0	0.3	14.76
2	1/1/2018 0:31	1/1/2018 0:45	1	2.32	1	N	186	231	1	11	0.5	0.5	3.08	0	0.3	15.38
2	1/1/2018 0:47	1/1/2018 1:26	1	9.49	1	N	231	116	1	35	0.5	0.5	9.08	0	0.3	45.38
1	1/1/2018 0:21	1/1/2018 0:28	2	2.5	1	N	141	145	1	9.5	0.5	0.5	2.7	0	0.3	13.5
1	1/1/2018 0:32	1/1/2018 0:47	1	4.6	1	N	145	263	1	15.5	0.5	0.5	4.2	0	0.3	21
1	1/1/2018 0:54	1/1/2018 1:03	1	3	1	N	141	146	2	10.5	0.5	0.5	0	0	0.3	11.8
1	1/1/2018 0:23	1/1/2018 0:52	1	7.3	1	N	90	82	1	26.5	0.5	0.5	1	5.76	0.3	34.56
1	1/1/2018 0:04	1/1/2018 0:15	1	1.3	1	N	144	234	1	9	0.5	0.5	2.05	0	0.3	12.35
1	1/1/2018 0:17	1/1/2018 0:41	1	0.8	1	N	234	164	2	14.5	0.5	0.5	0	0	0.3	15.8
1	1/1/2018 0:42	1/1/2018 0:44	1	0.1	1	N	164	164	2	3	0.5	0.5	0	0	0.3	4.3
1	1/1/2018 0:48	1/1/2018 0:55	2	0.2	1	N	164	164	1	6	0.5	0.5	1.45	0	0.3	8.75

Data transformation

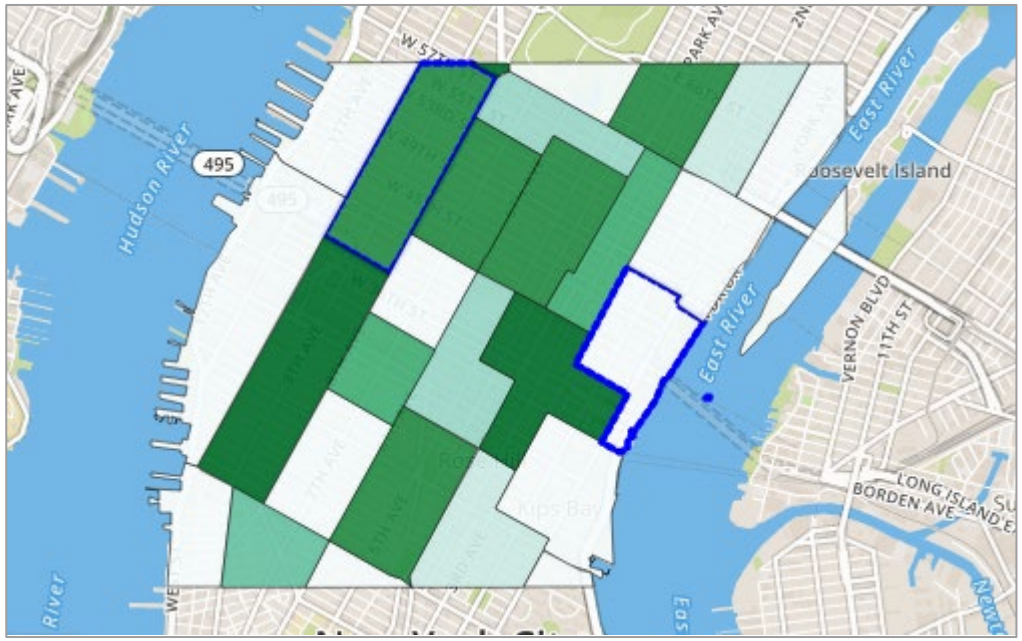
VendorID	tpep_pickup_datetime	tpep_dropoff_datetime	passenger_count	trip_distance	RatecodeID	store_and_f	PULocationID	DOLocationID	payment_	fare_amo	extra	mta_tax	tip_amou	tolls_amo	improvem	total_amount	Area
1	1/1/2018 0:21	1/1/2018 0:24	1	0.5	1	N	41	24	2	4.5	0.5	0.5	0	0	0.3	5.8	Midtown
1	1/1/2018 0:44	1/1/2018 1:03	1	2.7	1	N	239	140	2	14	0.5	0.5	0	0	0.3	15.3	Chelsea
1	1/1/2018 0:08	1/1/2018 0:14	2	0.8	1	N	262	141	1	6	0.5	0.5	1	0	0.3	8.3	Downtown
1	1/1/2018 0:20	1/1/2018 0:52	1	10.2	1	N	140	257	2	33.5	0.5	0.5	0	0	0.3	34.8	Downtown
1	1/1/2018 0:09	1/1/2018 0:27	2	2.5	1	N	246	239	1	12.5	0.5	0.5	2.75	0	0.3	16.55	Downtown
1	1/1/2018 0:29	1/1/2018 0:32	3	0.5	1	N	143	143	2	4.5	0.5	0.5	0	0	0.3	5.8	Midtown
1	1/1/2018 0:38	1/1/2018 0:48	2	1.7	1	N	50	239	1	9	0.5	0.5	2.05	0	0.3	12.35	Downtown
1	1/1/2018 0:49	1/1/2018 0:51	1	0.7	1	N	239	238	1	4	0.5	0.5	1	0	0.3	6.3	Downtown
1	1/1/2018 0:56	1/1/2018 1:01	1	1	1	N	238	24	1	5.5	0.5	0.5	1.7	0	0.3	8.5	Downtown
1	1/1/2018 0:17	1/1/2018 0:22	1	0.7	1	N	170	170	2	5.5	0.5	0.5	0	0	0.3	6.8	Downtown
1	1/1/2018 0:41	1/1/2018 0:46	1	0.6	1	N	162	229	1	5.5	0.5	0.5	1.35	0	0.3	8.15	Midtown
1	1/1/2018 0:52	1/1/2018 1:17	1	3.5	1	N	141	113	2	16.5	0.5	0.5	0	0	0.3	17.8	Downtown
2	1/1/2018 0:17	1/1/2018 0:22	1	1.04	1	N	137	224	2	5.5	0.5	0.5	0	0	0.3	6.8	Downtown
2	1/1/2018 0:24	1/1/2018 0:34	1	1.22	1	N	224	79	2	7.5	0.5	0.5	0	0	0.3	8.8	Downtown
2	1/1/2018 0:37	1/1/2018 0:53	1	1.92	1	N	234	100	2	10	0.5	0.5	0	0	0.3	11.8	Downtown
1	1/1/2018 0:35	1/1/2018 0:52	1	5.7	1	N	13	189	1	19	0.5	0.5	4.05	0	0.3	24.35	Downtown
2	1/1/2018 0:30	1/1/2018 1:13	1	3.74	1	N	48	236	1	25.5	0.5	0.5	6.7	0	0.3	33.5	Downtown
1	1/1/2018 0:21	1/1/2018 0:25	2	0.6	1	N	163	162	1	4.5	0.5	0.5	1.7	0	0.3	7.5	Midtown
1	1/1/2018 0:31	1/1/2018 1:07	1	10.9	1	N	229	61	2	35	0.5	0.5	0	0	0.3	36.3	Midtown
2	1/1/2018 0:15	1/1/2018 0:21	5	1.22	1	N	236	75	2	6	0.5	0.5	0	0	0.3	7.3	Midtown
2	1/1/2018 0:25	1/1/2018 0:45	5	3.13	1	N	263	143	2	13	0.5	0.5	0	0	0.3	14.3	Midtown
2	1/1/2018 0:51	1/1/2018 1:04	5	2.22	1	N	239	24	2	9.5	0.5	0.5	0	0	0.3	10.8	Midtown
2	1/1/2018 0:09	1/1/2018 0:30	1	2.93	1	N	90	233	1	14.5	0.5	0.5	2	0	0.3	17.8	Midtown
2	1/1/2018 0:32	1/1/2018 0:58	1	3.52	1	N	233	125	2	18	0.5	0.5	0	0	0.3	19.3	Midtown

Visual mapping

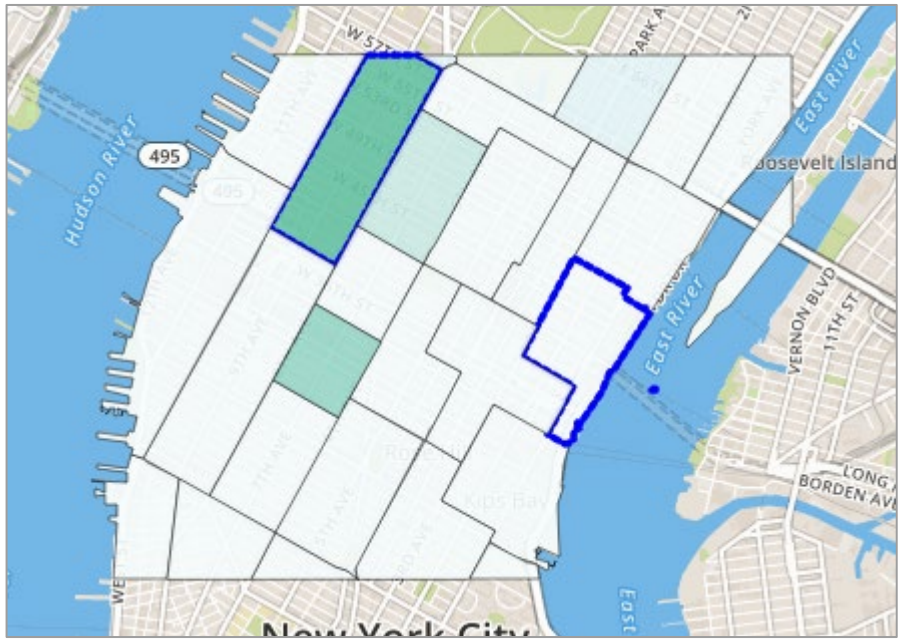
Quantitative data
Mark: polygon areas
Channel: color



Visual interaction



12pm– 2pm pickups

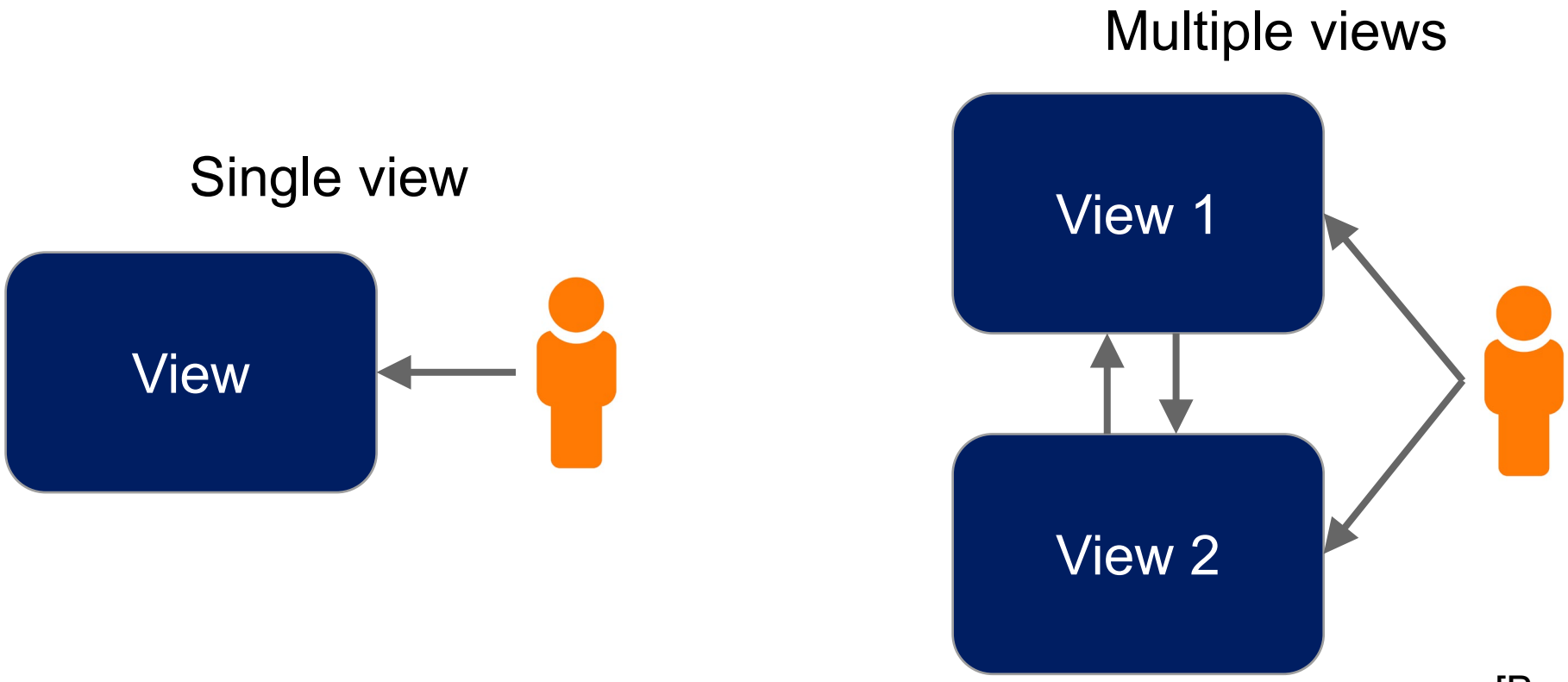


6am pickups

Interaction

- Interaction can be used to manipulate:
  - Data
  - Visual mapping
  - View
- Why manipulate visualizations?
  - Often not possible to visualize all the information needed to answer all questions in one single static view.
  - Interaction permits to adapt / change the visualization so that it's possible (or easier) to answer multiple questions.
  - Especially useful when visualization is used as a general-purpose application for data analysis and exploration.

Interaction



[Bertini, 2020]

Single view interactions

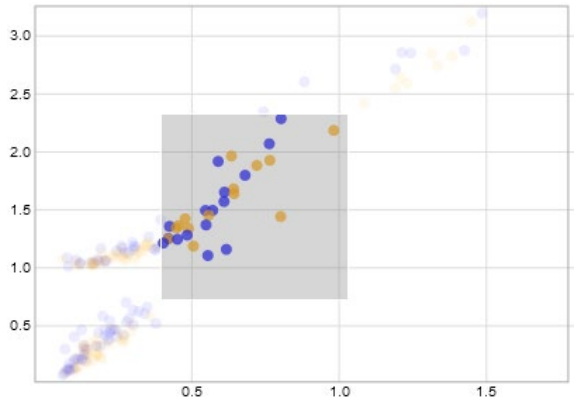
Manipulate	Methods
View	Selection Navigation Spatial arrangement
Mapping	Change mapping
Data	Aggregation Filtering

View interaction methods

- Selection: any action aimed at selecting one or more elements of the visualization.
  - Click → highlight (change color and/or borders, grey out the rest, etc.)
  - Hover → show more info (labels, info in linked view, etc.)
  - Click + drag → apply operation
- Navigation: changing the level of details and moving the viewport.
- Spatial arrangement: changing the way elements of the visualization are arranged / ordered.
  - Reordering → make visual patterns apparent.

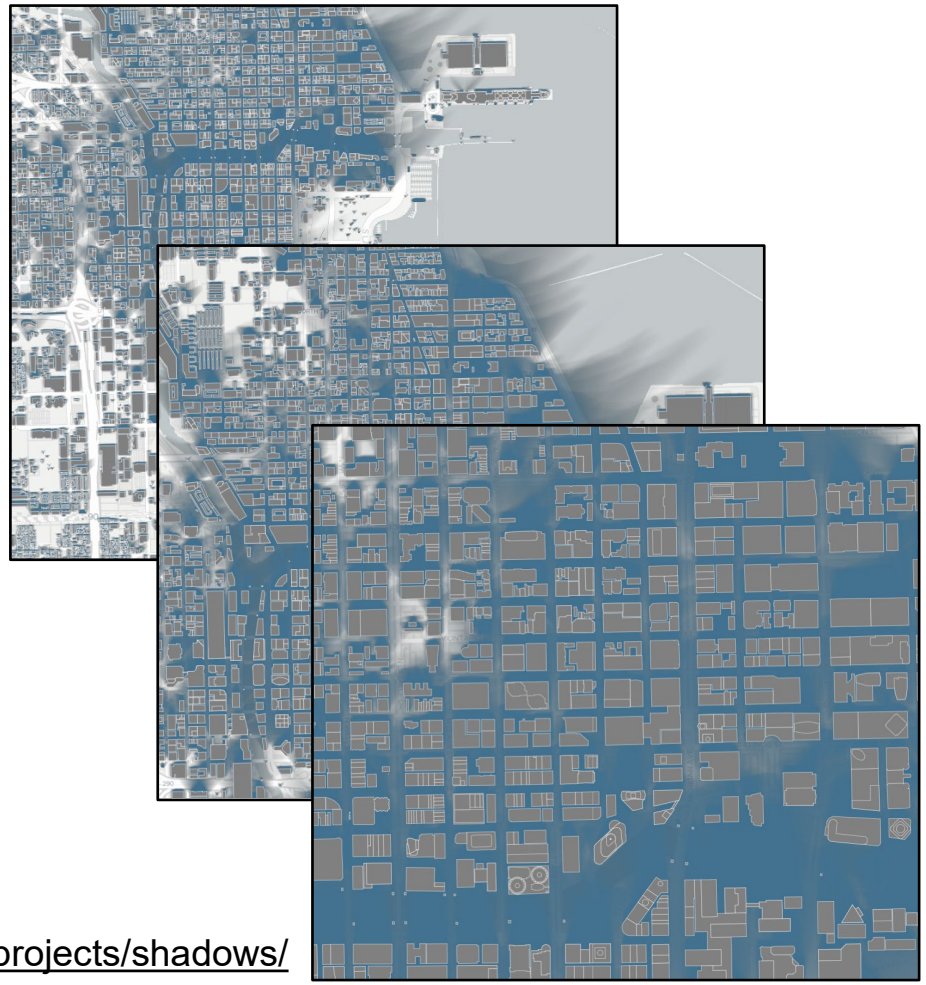
View interaction methods

Selection



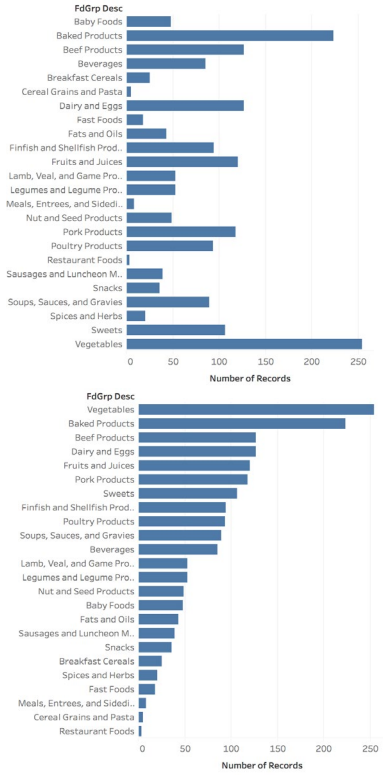
https://vgc.poly.edu/projects/urban-pulse/

Navigation



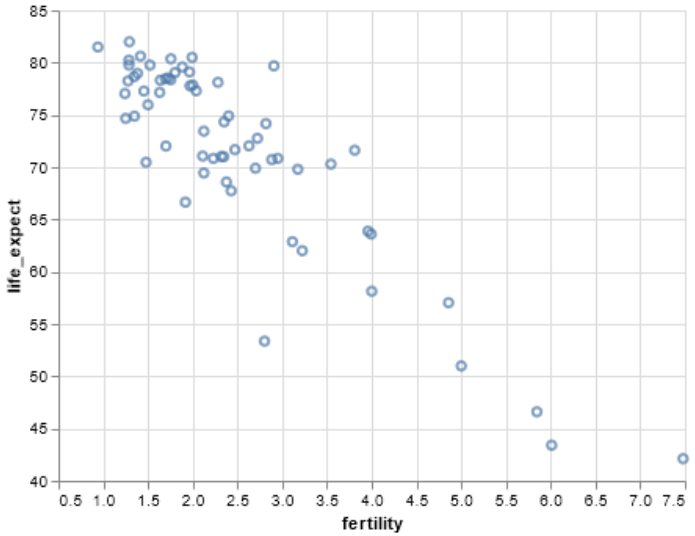
https://vgc.poly.edu/projects/shadows/

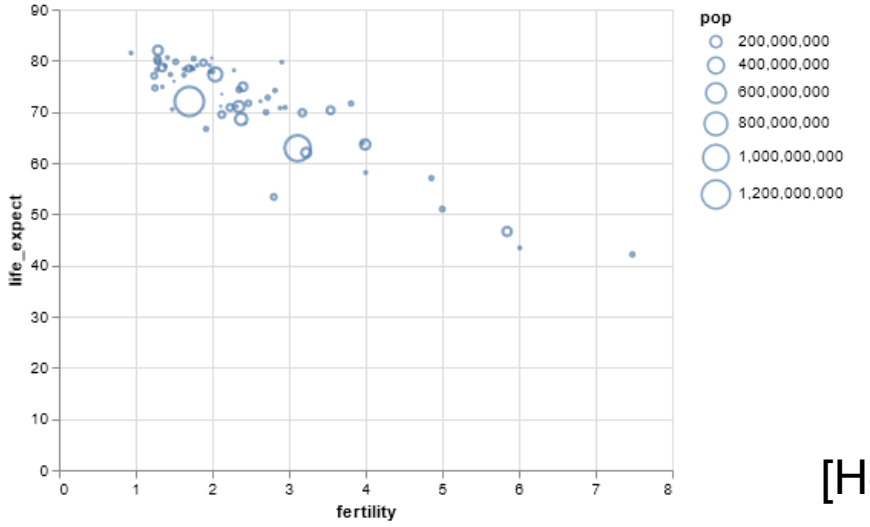
Spatial arrangement



Mapping interaction method

- Change mapping: changing the way attributes are encoded with visual channels.
  - Completely different plot or changes in properties of a given plot.





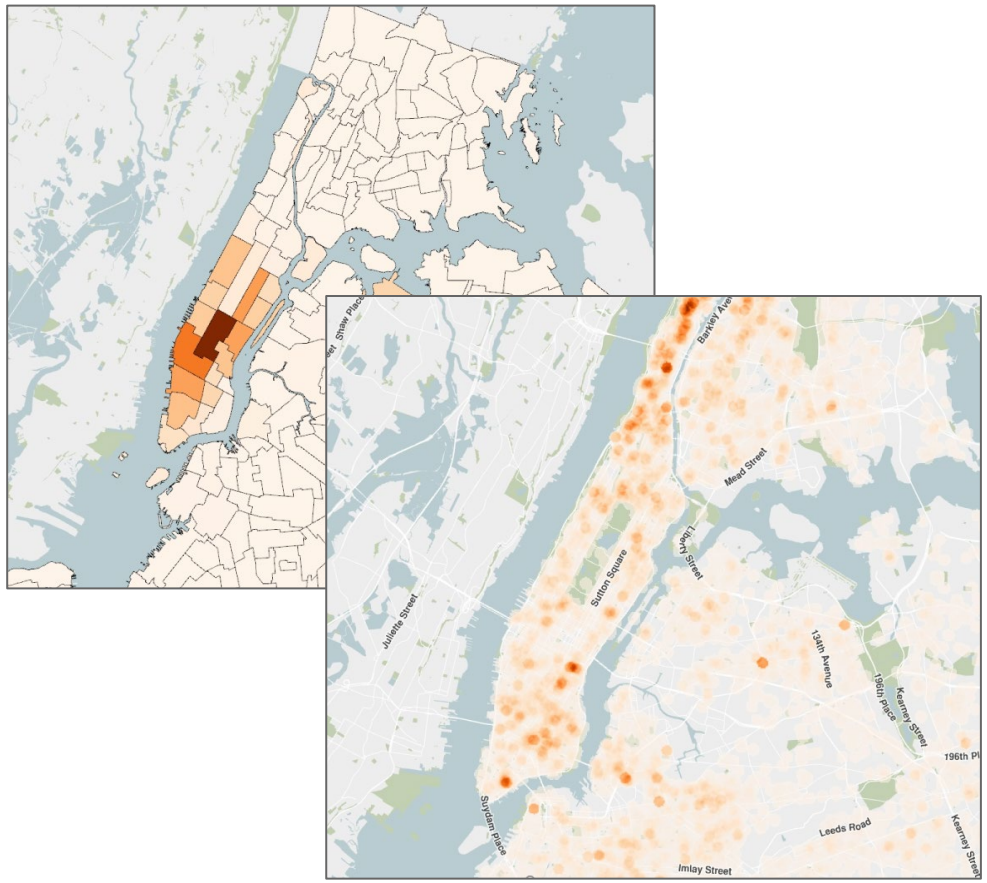
[Heer, 2020]

Data interaction methods

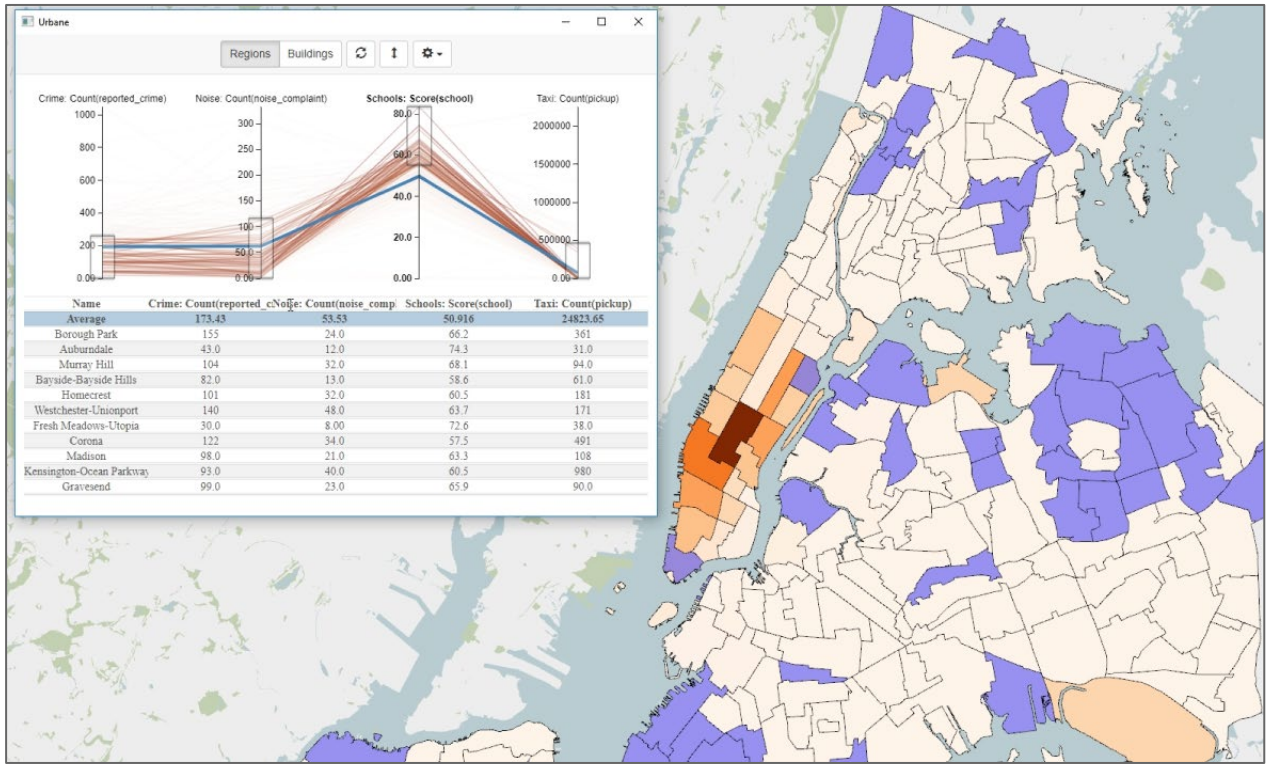
- Aggregation: changing the level of granularity of a given data set.
  - Space and time are hierarchical and often require observing patterns at different resolutions.
- Filtering: filtering data interactively according to some criteria or constraints.

Date interaction methods

Aggregation

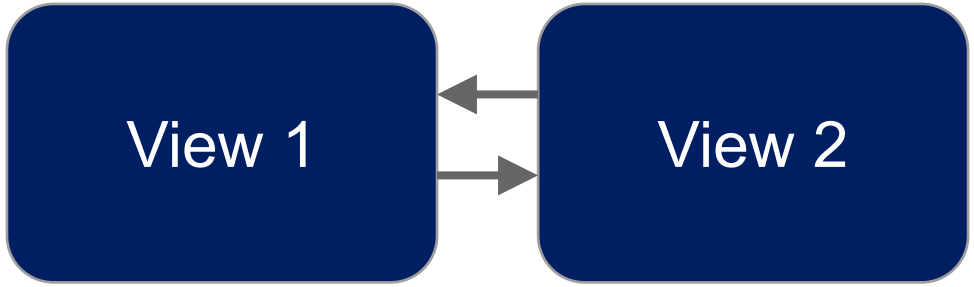


Filtering



Multiple linked views

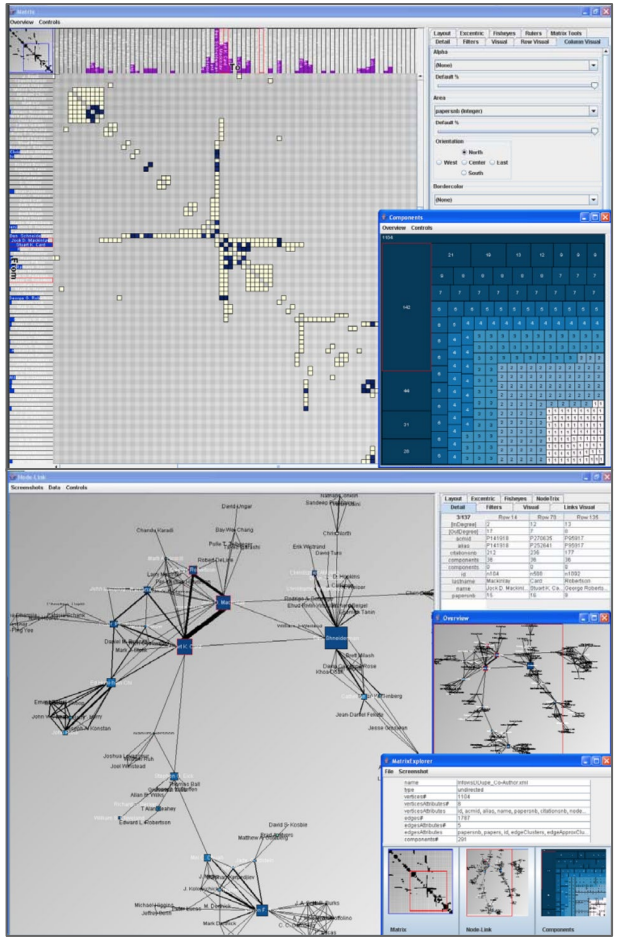
- Why multiple linked views?
  - Show different properties of the same data simultaneously.
  - Use one view to navigate, select, filter information in the other view.



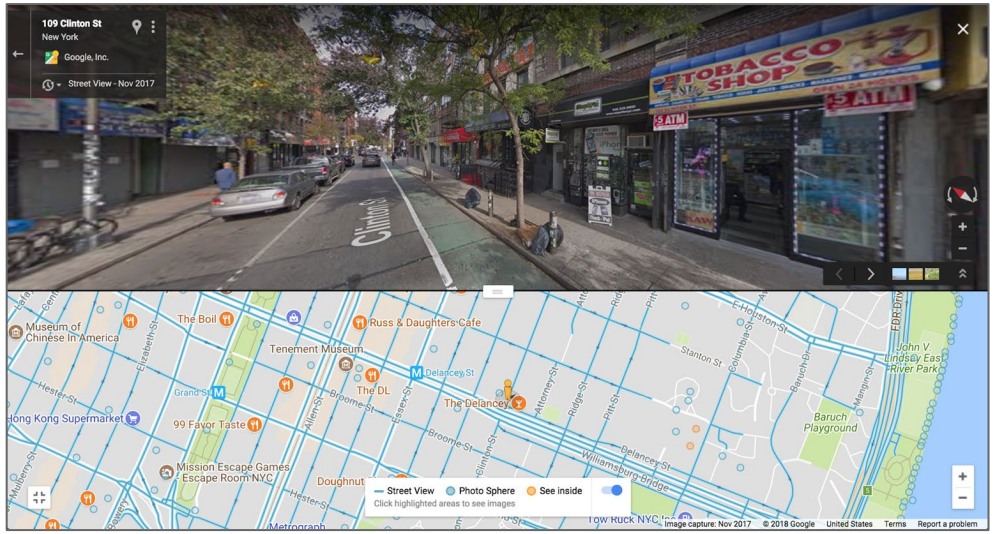
How to show different properties?

- Different information
  - Subset of data
  - Different attributes
  - Different granularity
  - Transformation
- Different representation

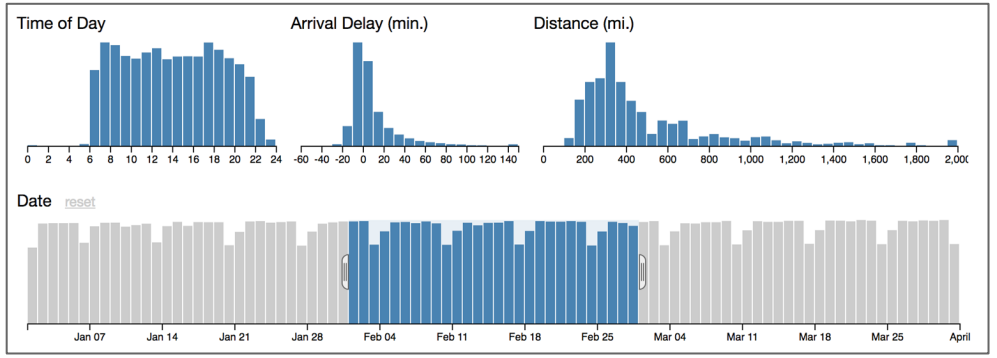
Multiple linked views



Same information,
different representation
[Riche, 2006]

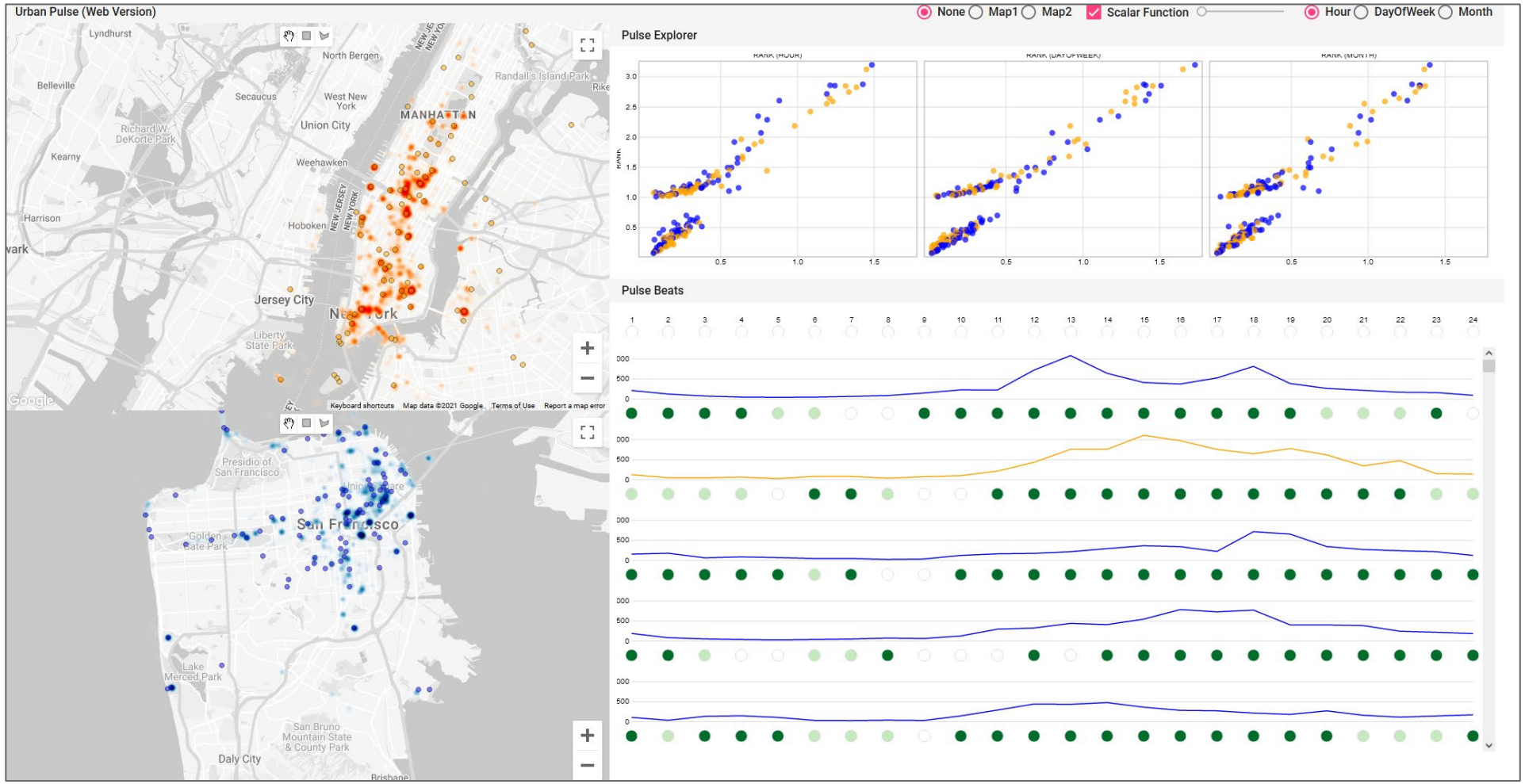


Different information & representation



Different information,
same representation

Multiple linked views

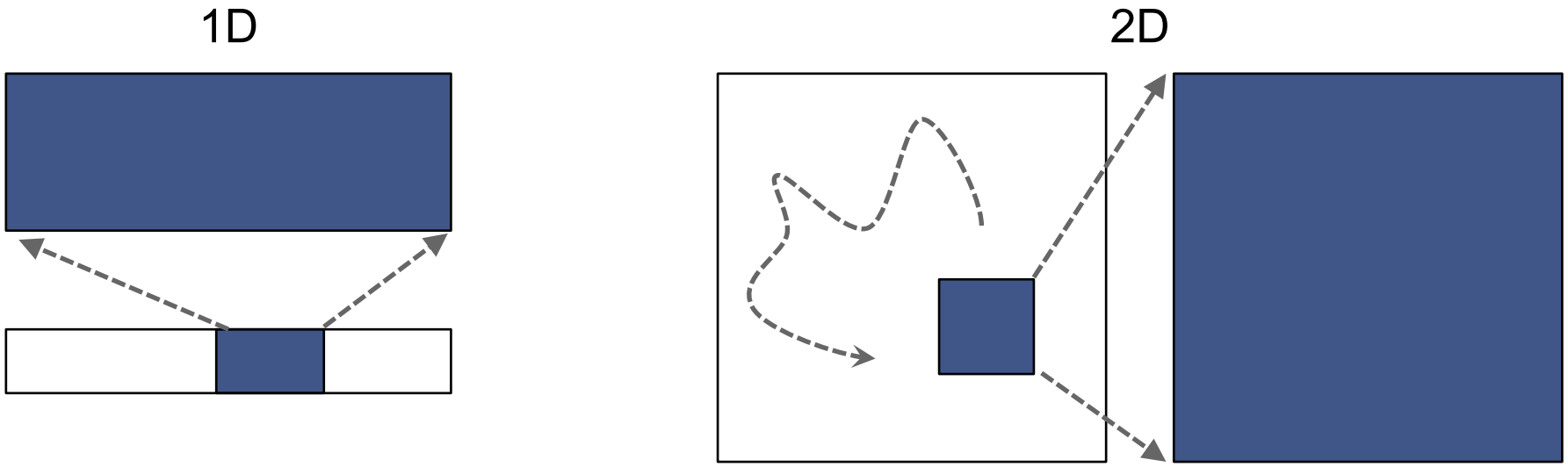


http://vgc.poly.edu/projects/urban-pulse/

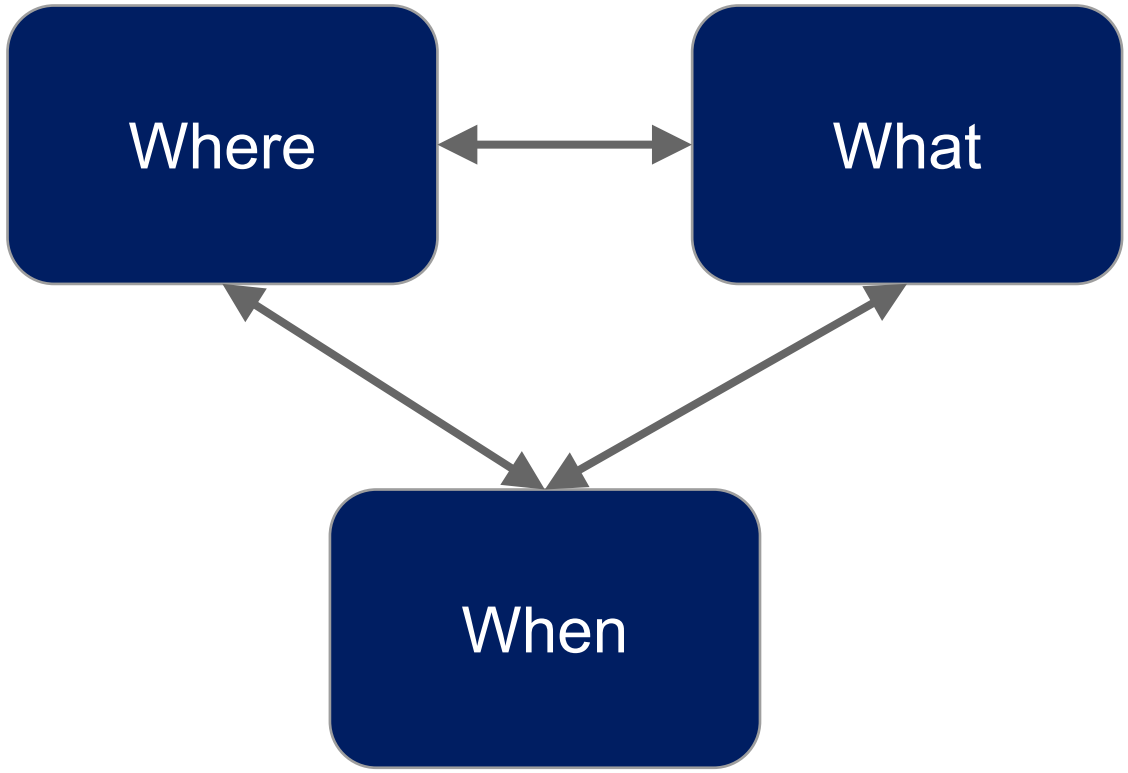
Overview + detail

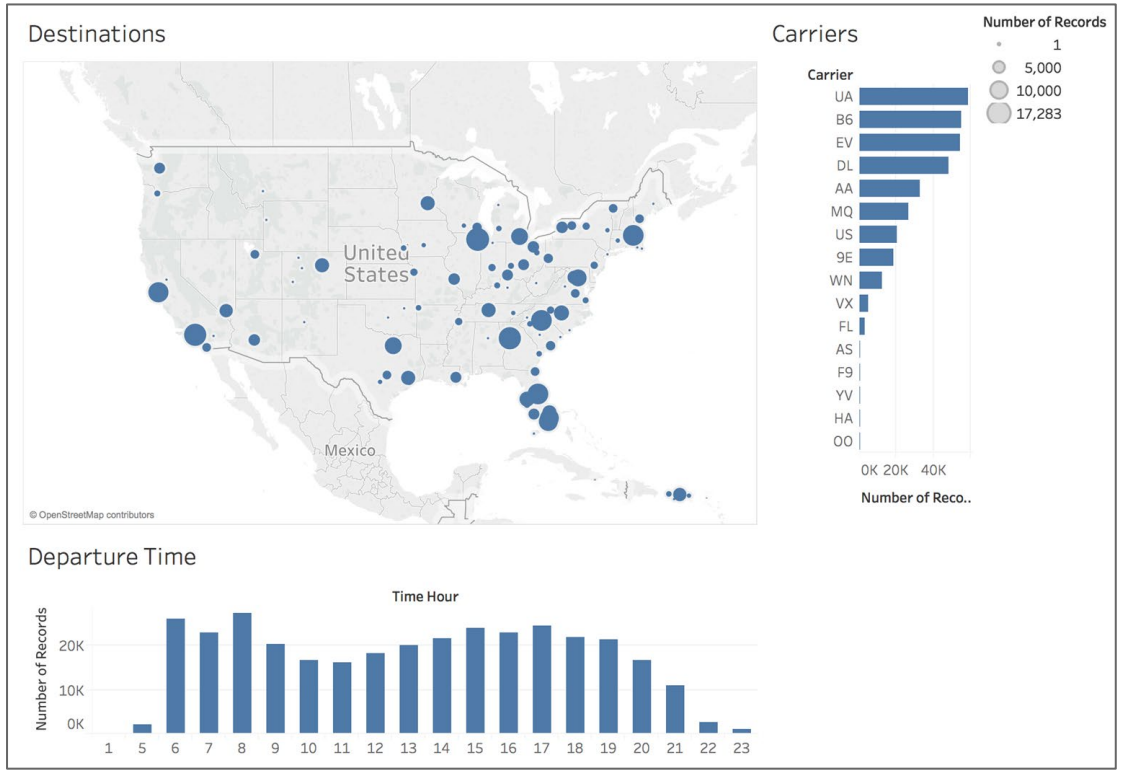
- Visualization mantra:
  "O*verview first, zoom and filter, then details on demand*"

[Shneiderman, 1996]



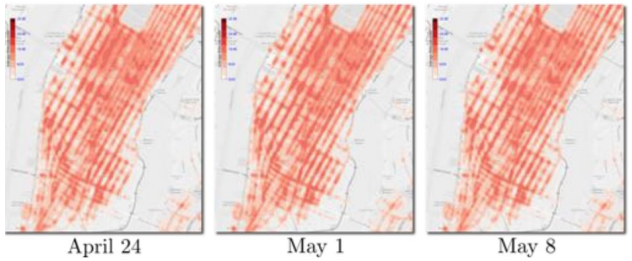
Where, what, when

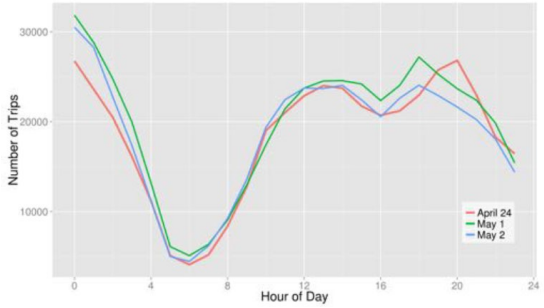




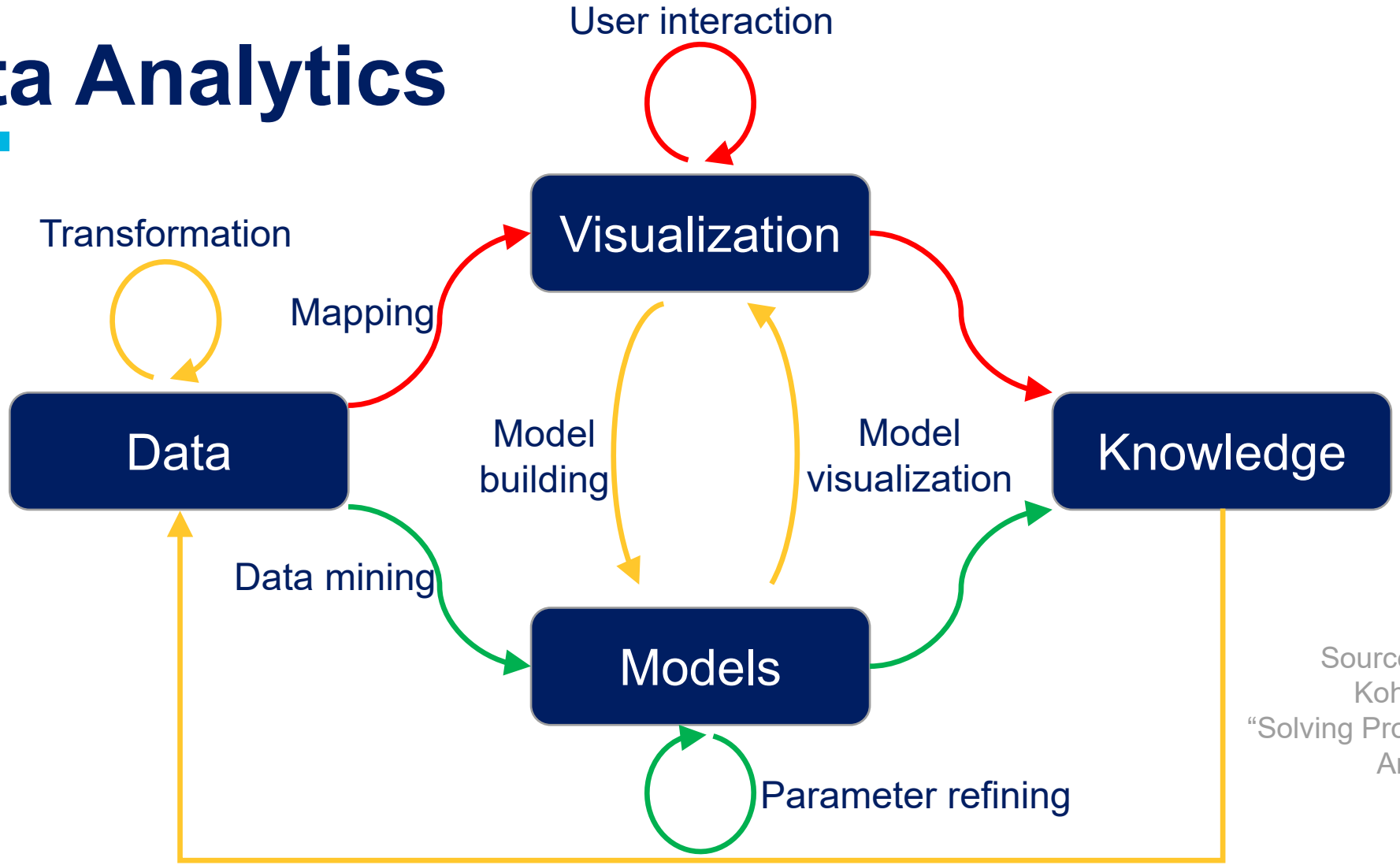
Big data challenges

- 365*24 1-hour slices in one year.
- Which slides are interesting?





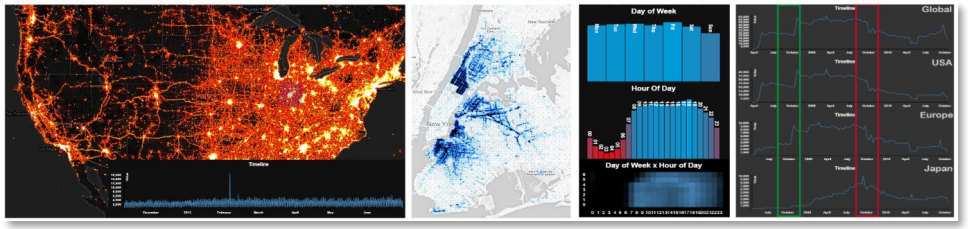
Data Analytics



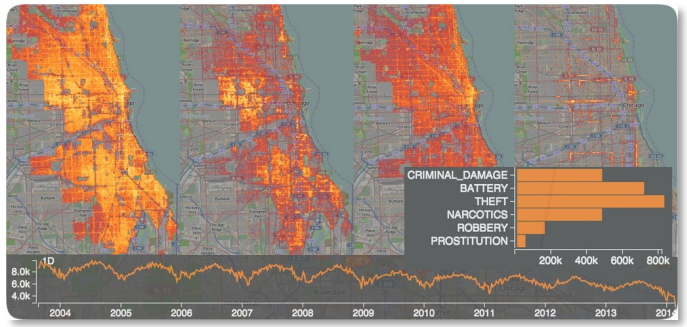
Source: Kleim and Kohlhammer, "Solving Problems with Visual Analytics"

Accelerating data interaction methods

OLAP queries

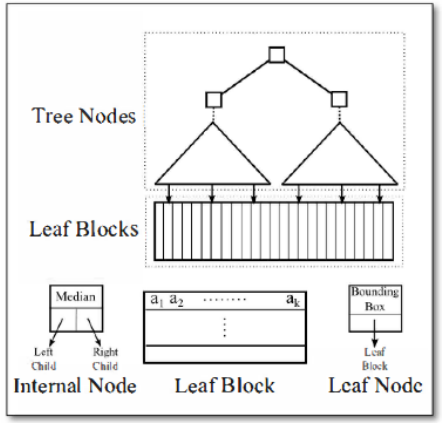


Hashedcubes [Pahins et al., 2017]



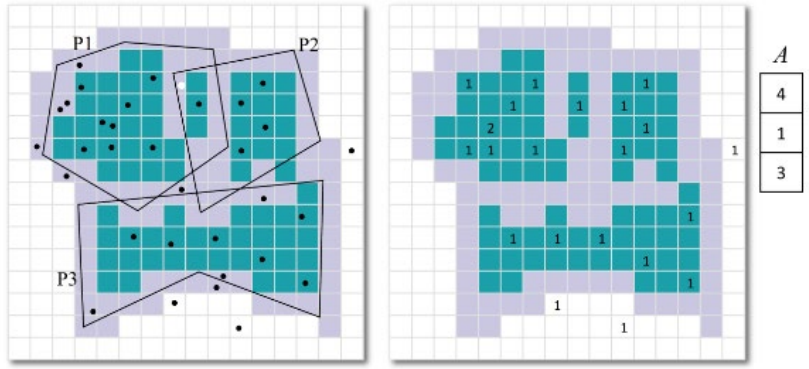
Nanocube [Lins et al., 2013]
TopKube [Miranda et al., 2018]

Selection



STIG [Doraiswamy et al., 2015]

Spatiotemporal joins



Raster join [Tzirita Zacharatou, Doraiswamy et al., 2018]

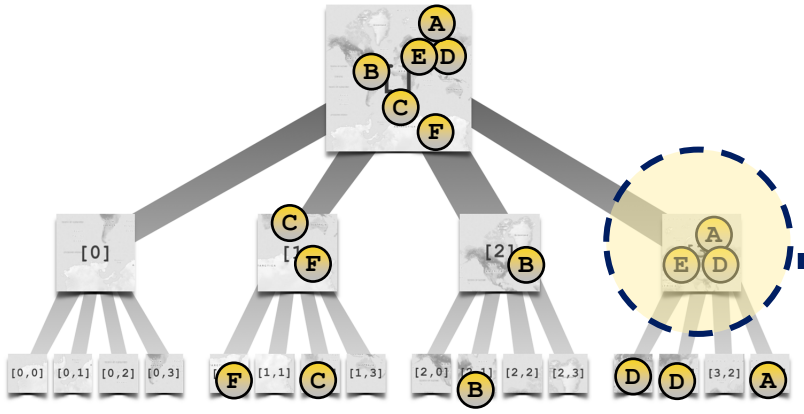
Datacube model

Following datacube model, aggregate every record along a hierarchy of bins.

The data structure is a mapping of bins to a pre-computed summary (e.g., count, timeseries).

latitude	longitude	keyword
42.102908	-73.242852	#phoenix
29.617161	-81.636398	#phoenix
23.014051	75.120052	#la
26.014051	75.120052	#nyc
28.014051	74.120052	#la
23.014051	75.120052	#phoenix

	latitude	longitude
A	42.102908	-73.242852
B	29.617161	-81.636398
C	23.014051	75.120052
D	26.014051	75.120052
E	28.014051	74.120052
F	29.61161	-81.63638



K	c	p
0	10	1
1	22	2
2	15	0

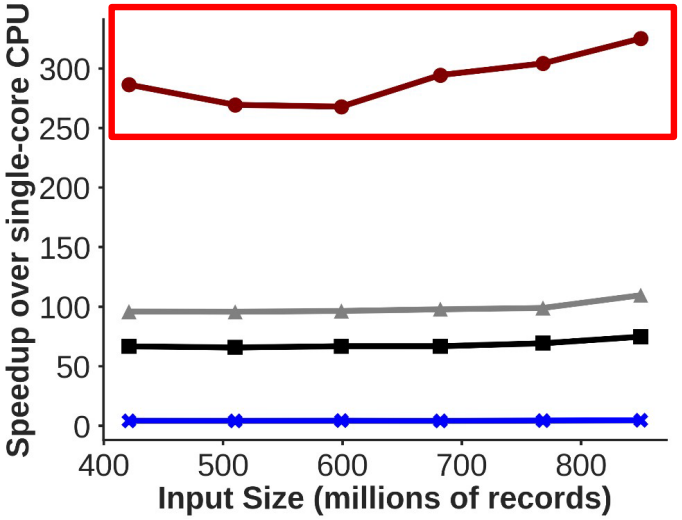
Data structures for visualization

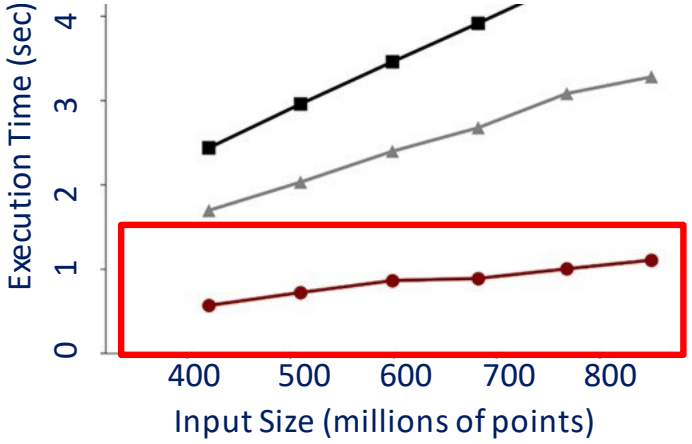
- immense [Liu et al., 2013]
- Nanocube [Lins et al., 2013]
- TopKube [Miranda et al., 2018]
- Time Lattice [Miranda et al., 2019]
- Learned cubes
- …

Raster Join: performance evaluation

NYC taxi data (over 868 million points), 260 NYC neighborhood polygons

Laptop with i7 Quad-Core@2.8 GHz, 16 GB RAM, GTX 1060 GPU



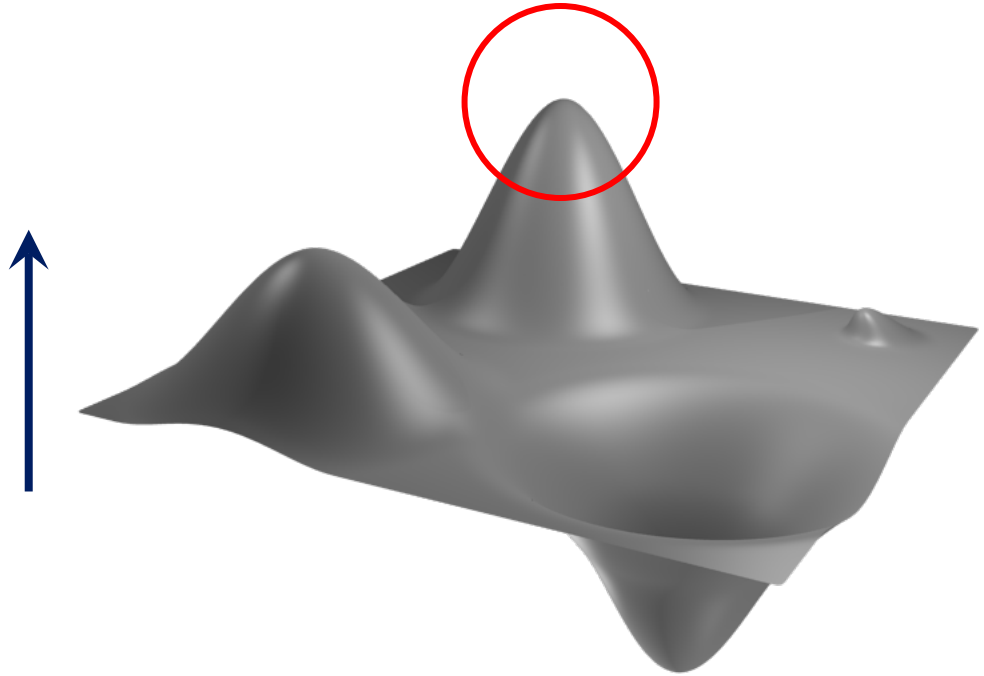


300x speedup

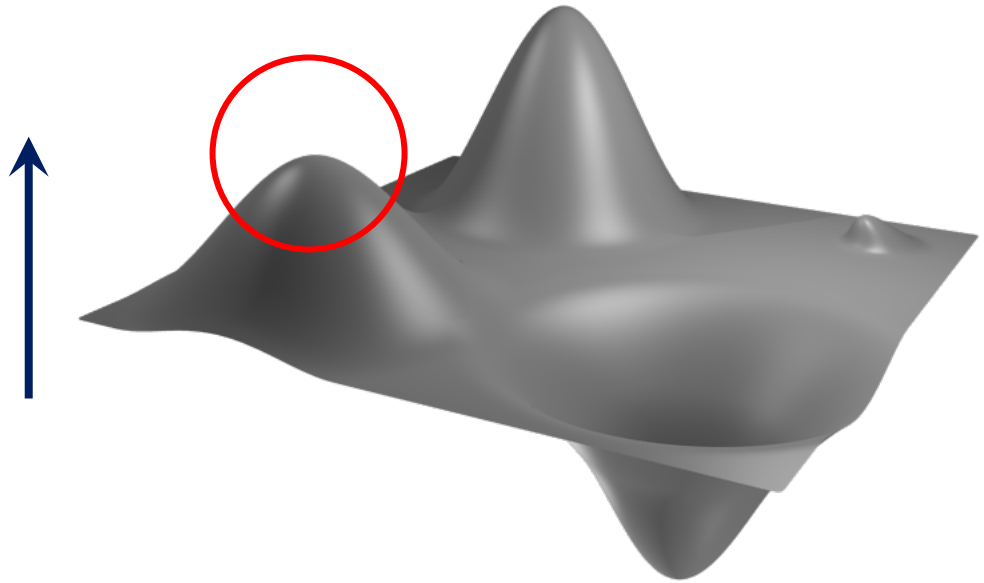
Taxi patterns

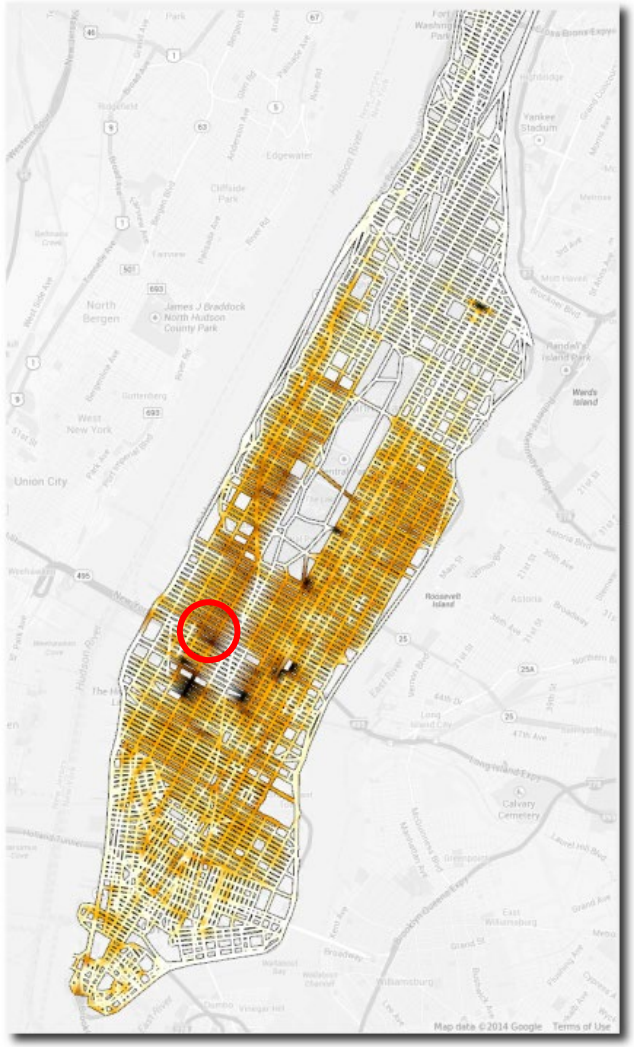
- NYC taxi data:
  - ~175 million trips / year
  - Spatiotemporal
  - Other attributes:
    - Fare, tip
    - Distance
    - Duration
    - …

Topology of the data

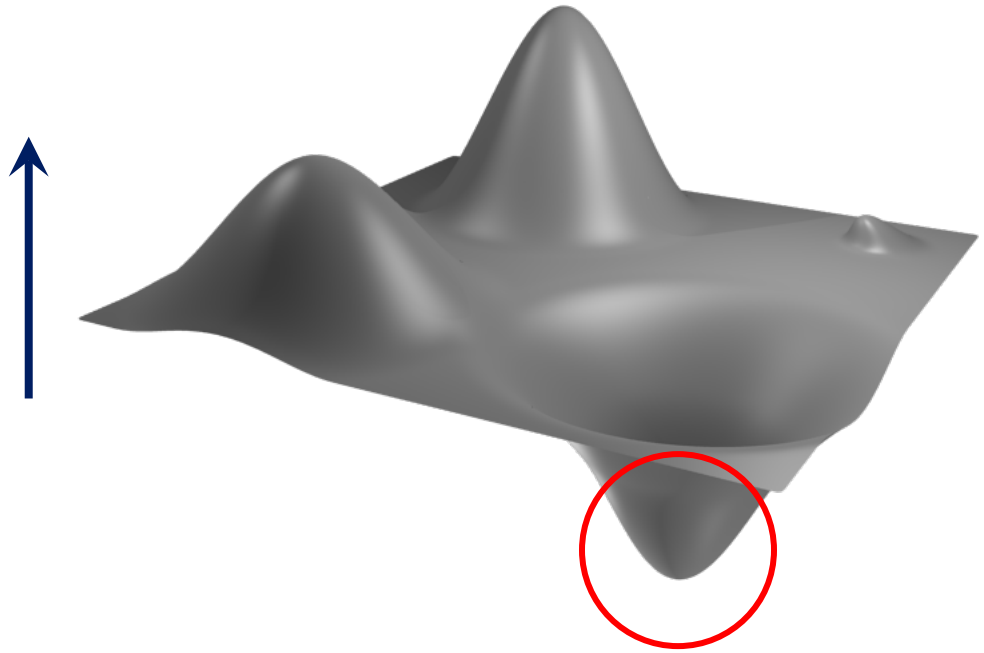


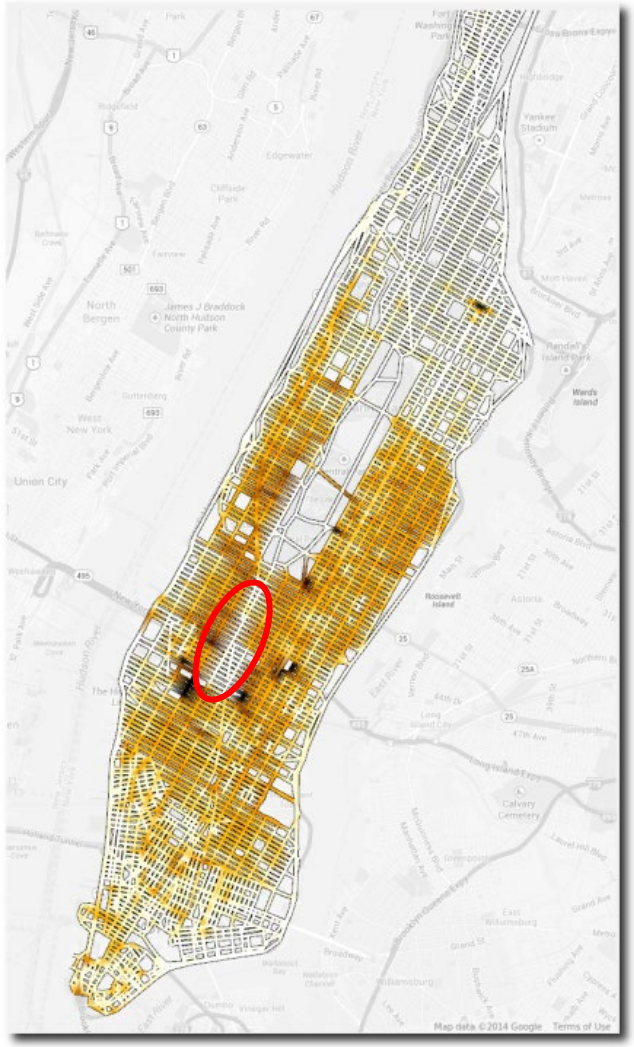
Topology of the data



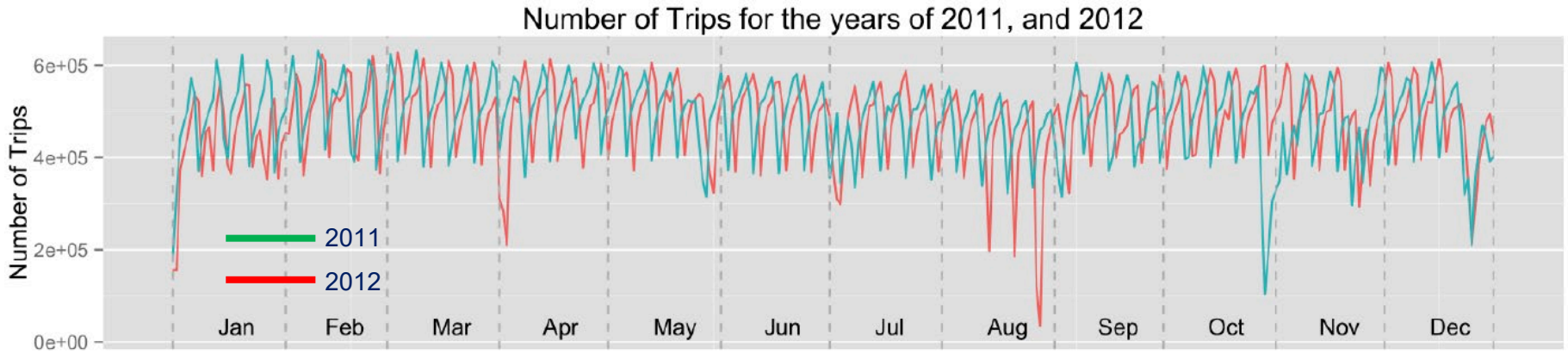


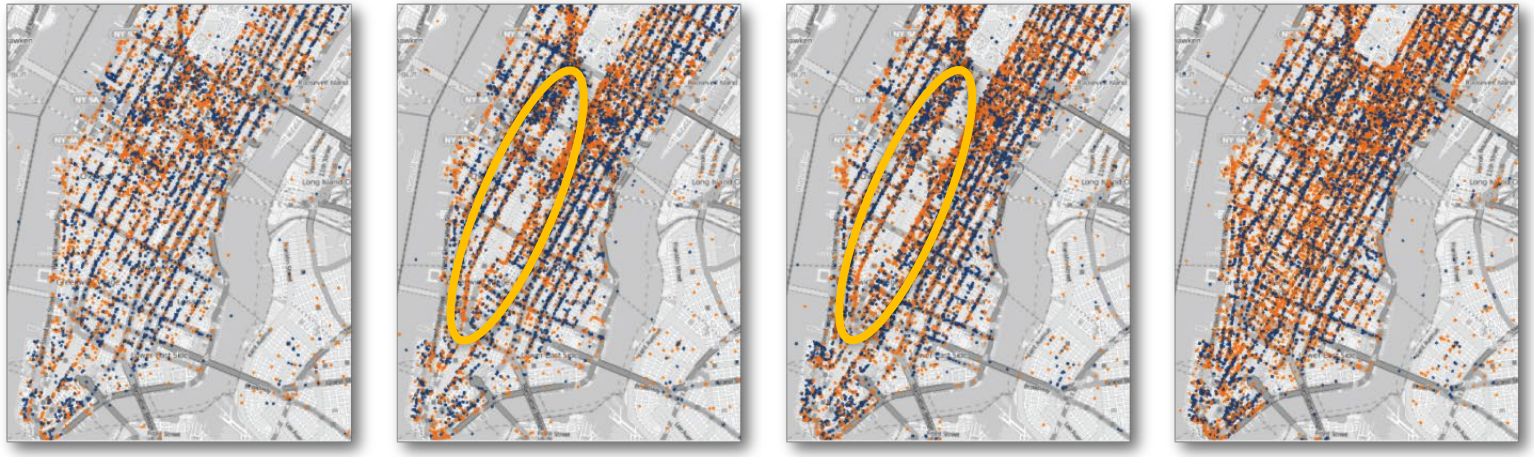
Topology of the data





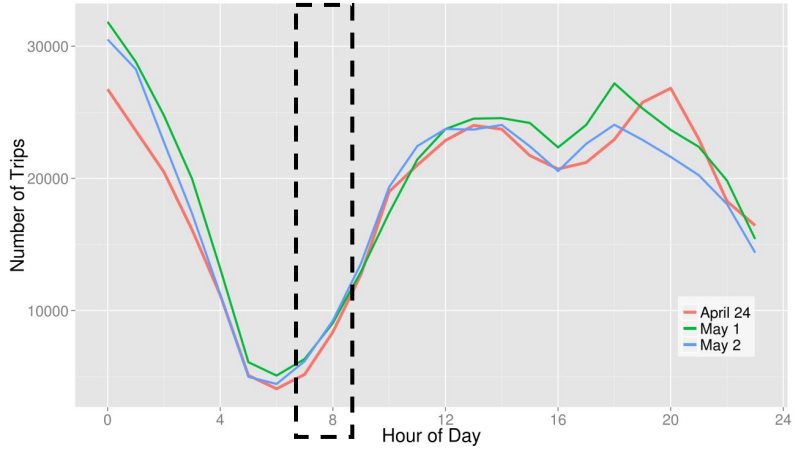
Taxi data slices



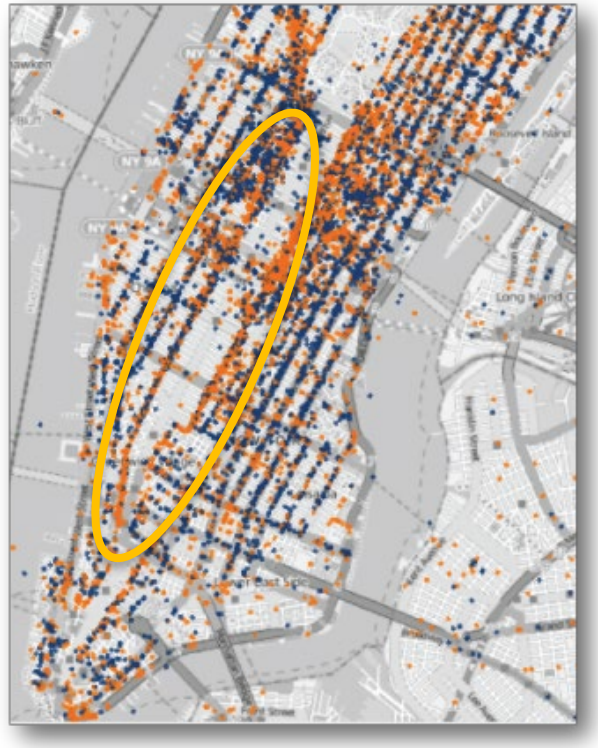


7am - 8am | 8am - 9am | 9am - 10am | 10am - 11am

Taxi data slices

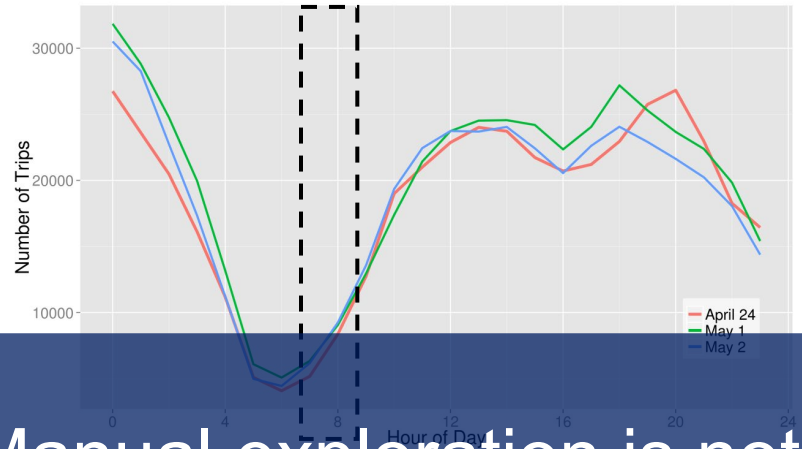


April 24 May 1 May 8

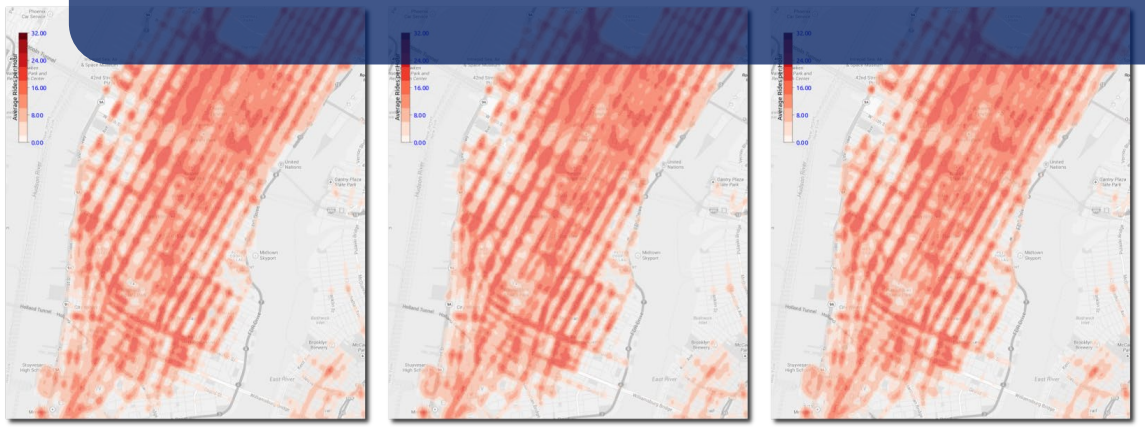


8am - 9am

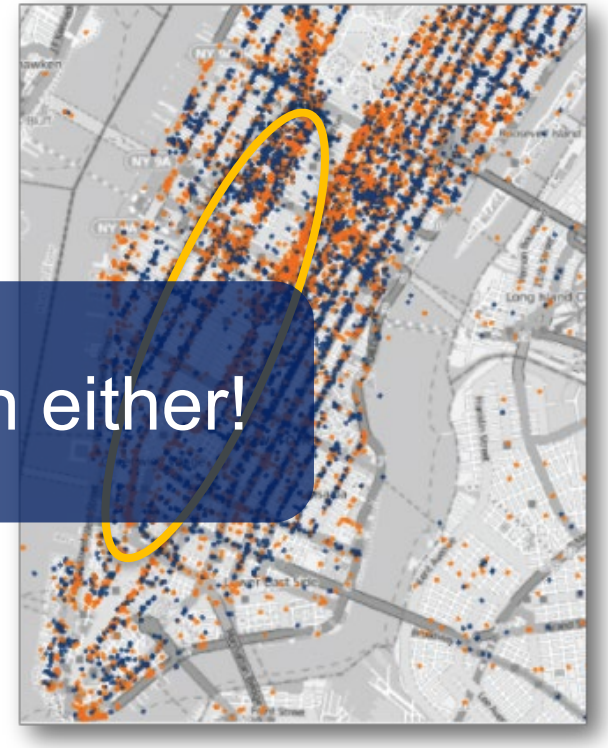
Taxi data slices



Manual exploration is not an option either!



April 24 May 1 May 8



8am - 9am

CS524: Big Data Visualization & Analytics