

Interaction & Multiple views

CS424: Visualization & Visual Analytics

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<https://fmiranda.me>

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_fwd_location	PULocationID	DOLocationID	payment_type	fare_amount	extra	mta_tax	tip_amount	tolls_amount	improvement_amount	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	tpcp_pickup_datetime	tpcp_dropoff_datetime	passenger_count	trip_distance	RatecodeID	store_and_fPULocationID	DOLocationID	payment_fare_amo	extra	mta_tax	tip_amo	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	8.75

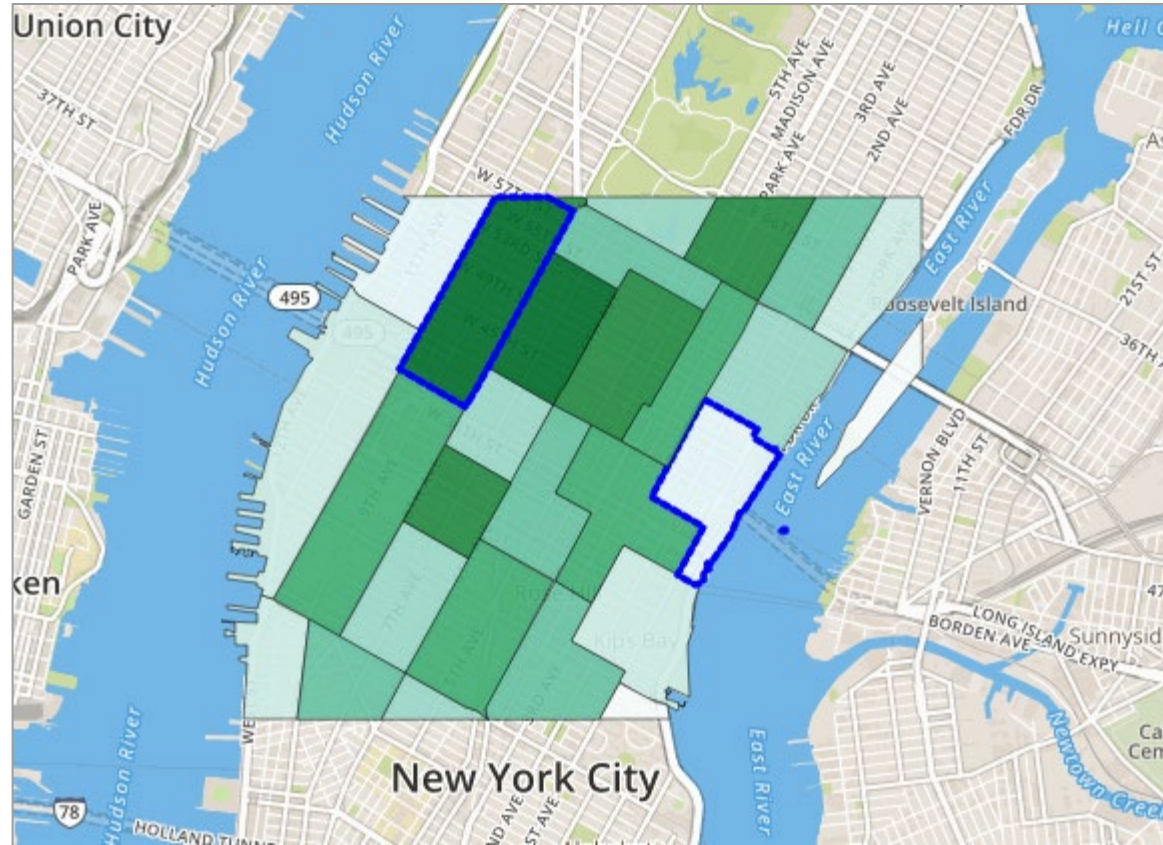


Data transformation

VendorID	tpep_pickup_datetime	tpep_dropoff_datetime	passenger_count	trip_distance	RatecodeID	store_and_fwd_flag	PULocationID	DOLocationID	payment_type	fare_amount	extra	mta_tax	tip_amount	tolls_amount	improvement_surcharge	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	5.3	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	34.3	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	16.5	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	5.3	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	12.3	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	8.3	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	6.3	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	8.1	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	17.3	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	6.3	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	8.3	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	11.3	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	24.3	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	7.3	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	10.3	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	17.3	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



Visualization so far...



Up until now in the course, all visual representations were presented as static pictures...

... but digital devices enable people to interact with graphical representations.

Interaction



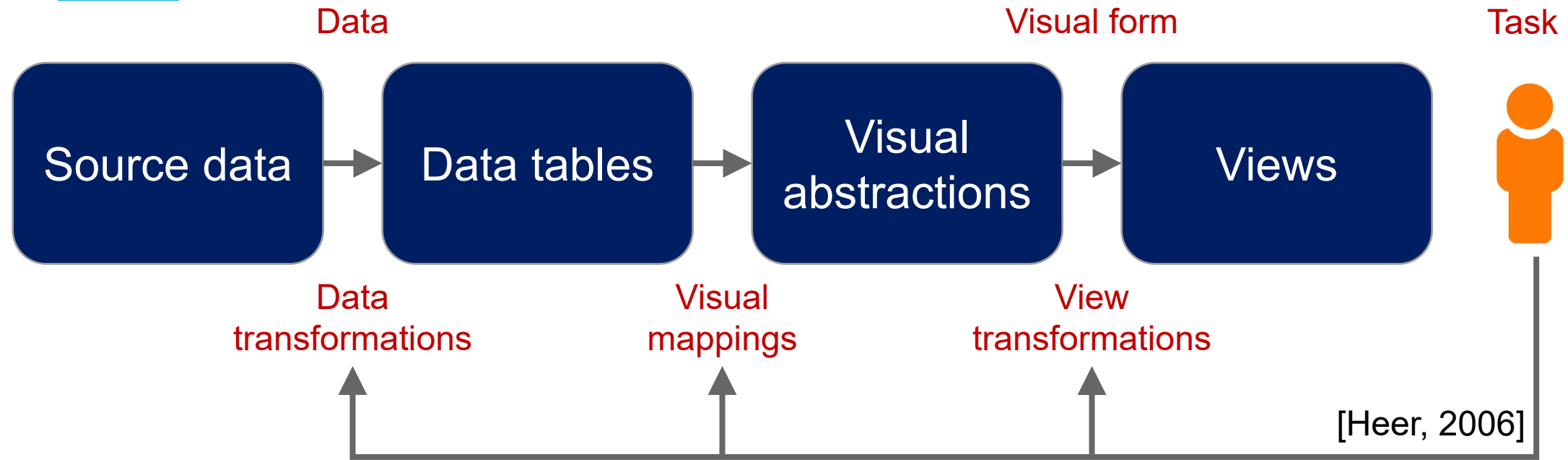
- Two main questions:
 - What is **possible** to do with interaction in visualization?
 - When is it **useful** to make visualizations interactive?

Interaction



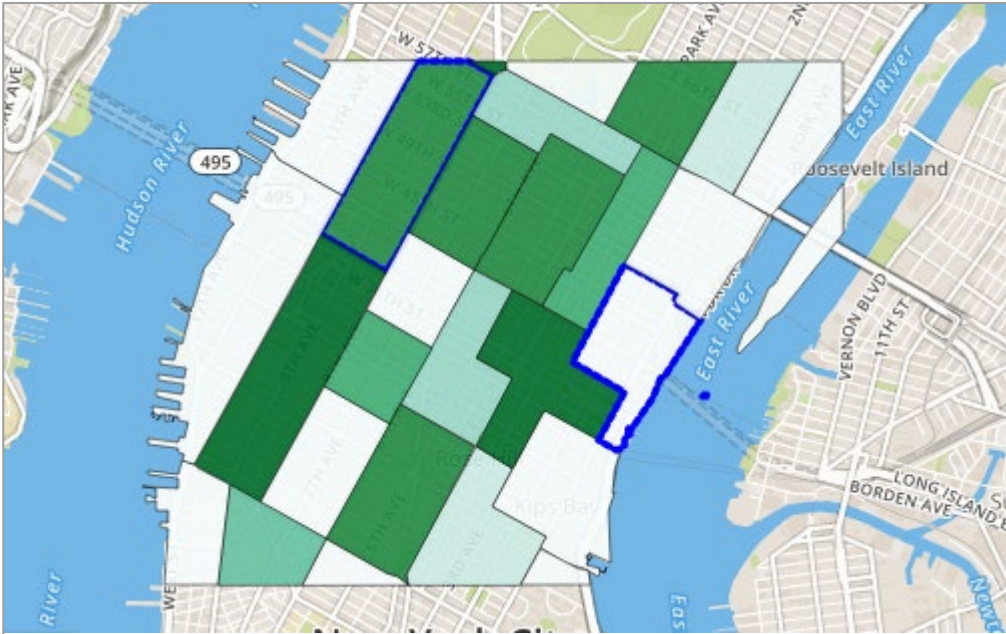
- What we will cover:
 - Interaction methods.
 - Multiple linked views.
 - Why / when these methods are useful.

Visualization design

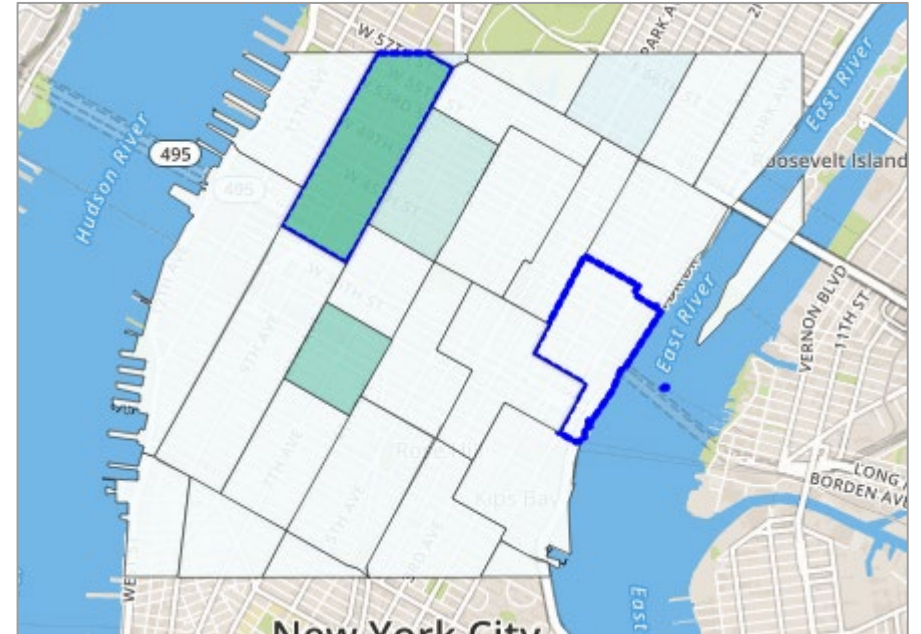


- Creating a data visualization is easy; creating a **good** visualization is hard.
- Visualization design space is huge, it's important to make good choices in each stage.

Visual interaction



12pm– 2pm pickups



6am pickups

Interaction



- Interaction can be used to manipulate:
 - Data
 - Visual mapping
 - View

Manipulating the data

- Data transformations (see last lectures):
- 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.

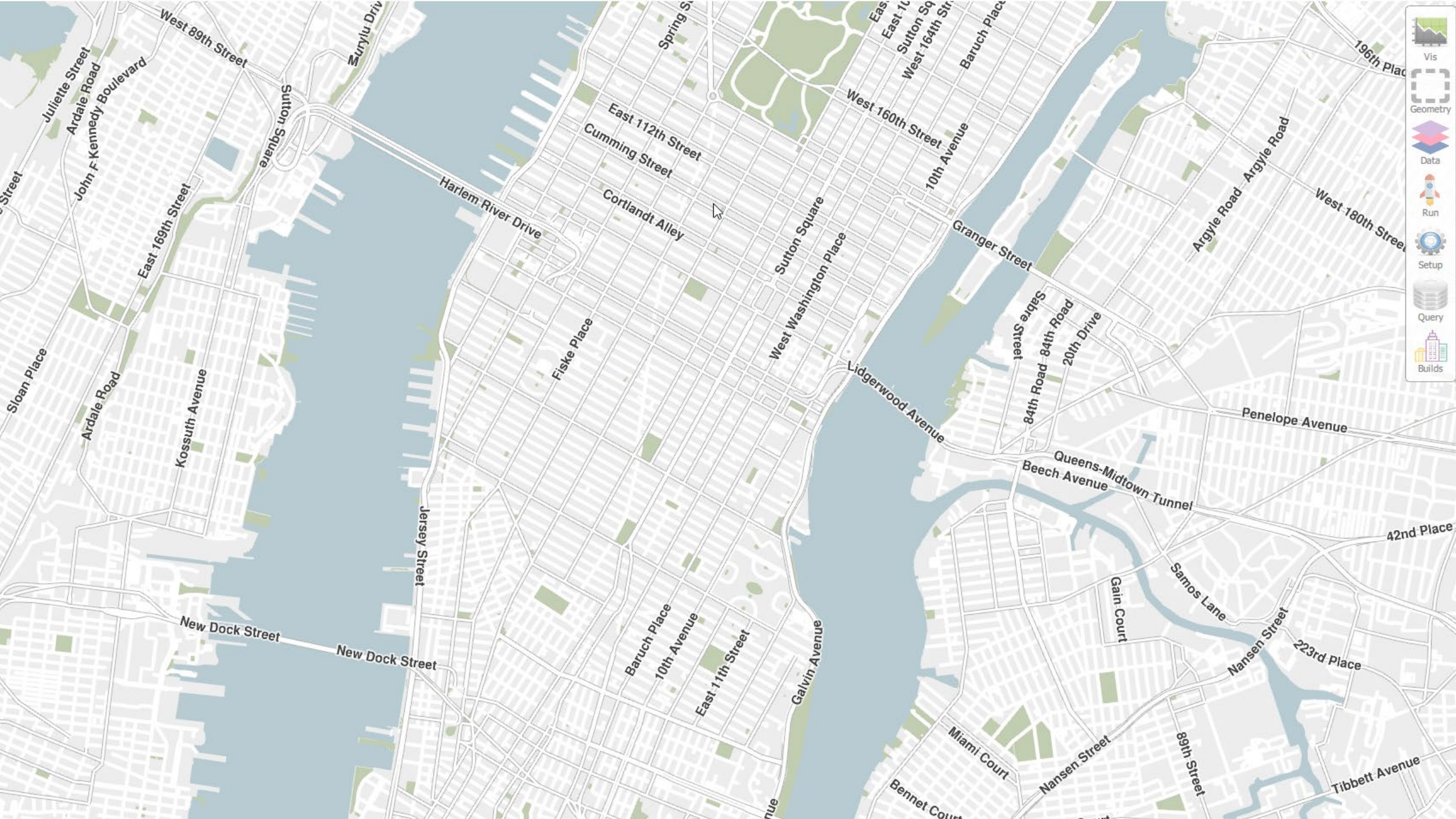
The screenshot shows the UrbanSim application interface. The main window displays a map of New York City with regions highlighted in orange and blue. A window titled 'UrbanSim' is open, showing four line charts and a table of data.

The charts display the following data series:

- Crime: Count(reported_crime)**: Y-axis scale 0.00 to 1000.
- Noise: Count(noise_complaint)**: Y-axis scale 0.00 to 300.
- Schools: Score(school)**: Y-axis scale 0.00 to 80.0.
- Taxi: Count(pickup)**: Y-axis scale 0.00 to 2000000.

The table below shows the data for various regions:

Name	Crime: Count(reported_crime)	Noise: Count(noise_complaint)	Schools: Score(school)	Taxi: Count(pickup)
Average	173.43	33.53	50.916	14823.65
Borough Park	155	24.0	66.2	361
Auburndale	43.0	12.0	74.3	31.0
Murray Hill	104	32.0	68.1	94.0
Bayside-Bayside Hills	82.0	13.0	58.6	61.0
Homerest	101	32.0	60.5	181
Westchester-Unionport	140	48.0	63.7	171
Fresh Meadows-Utopia	30.0	8.00	72.6	38.0
Corona	122	34.0	57.5	491
Madison	98.0	21.0	63.3	108
Kensington-Ocean Parkway	93.0	40.0	60.5	980
Gravesend	99.0	23.0	65.9	90.0



-  Vis
-  Geometry
-  Data
-  Run
-  Setup
-  Query
-  Builds

Manipulating the view

- **Selection**: any action aimed at selecting one or more elements of the visualization.

Action:

- Click
- Hover
- Click + Drag



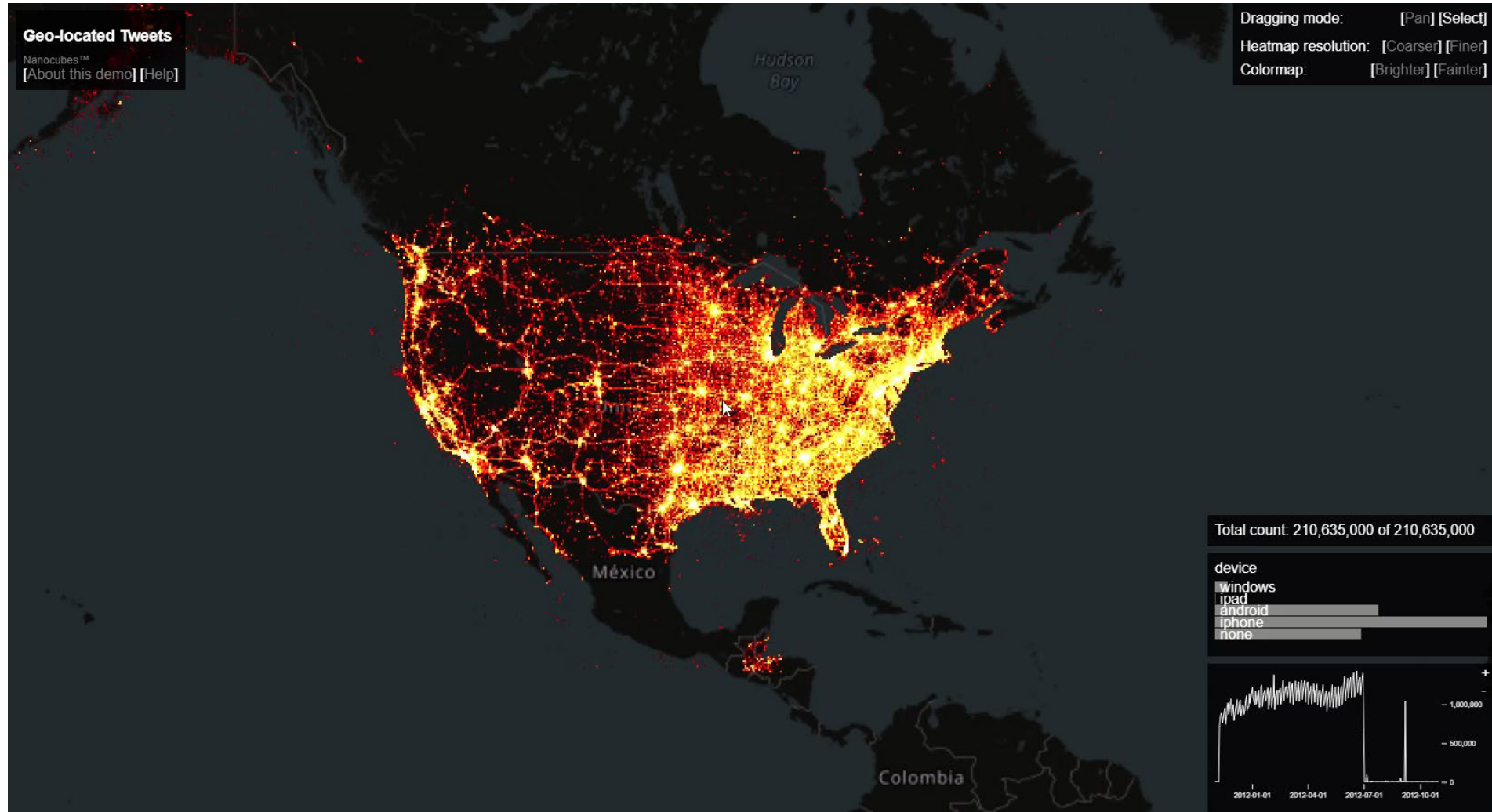
Change:

- Highlight
- Show more info
- Apply operation

Manipulating the view

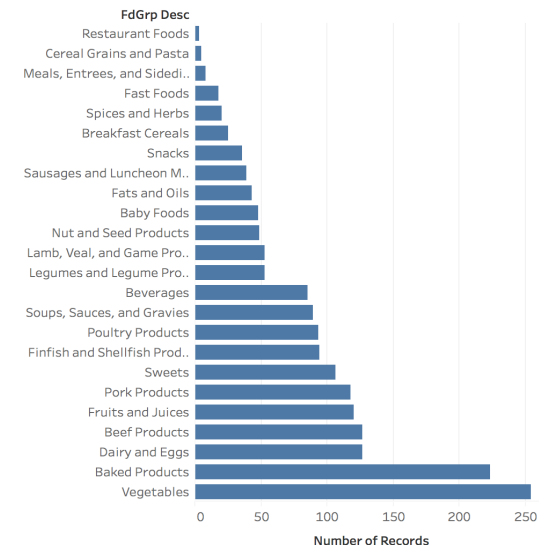
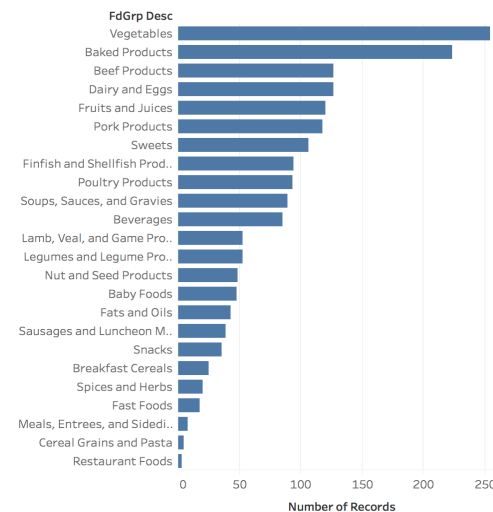
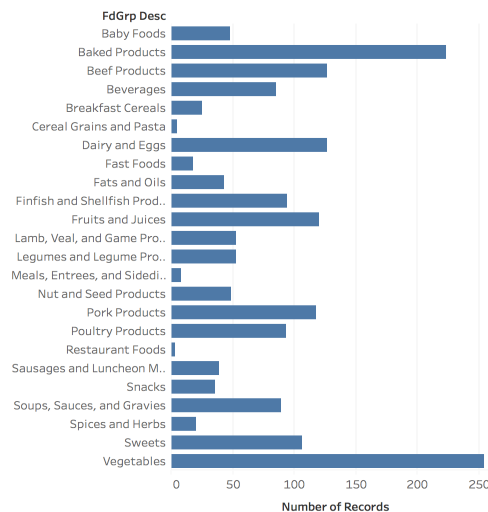
- **Navigation**: changing the level of details and moving the viewpoint.
 - Panning and zooming.
 - Semantic zooming: type and quantity of information show changes with the zoom level.

Manipulating the view: panning and zooming



Manipulating the view

- **Spatial arrangement**: change the way elements of the visualization are arranged / ordered.
 - Reordering: fundamental to make visual patterns apparent.

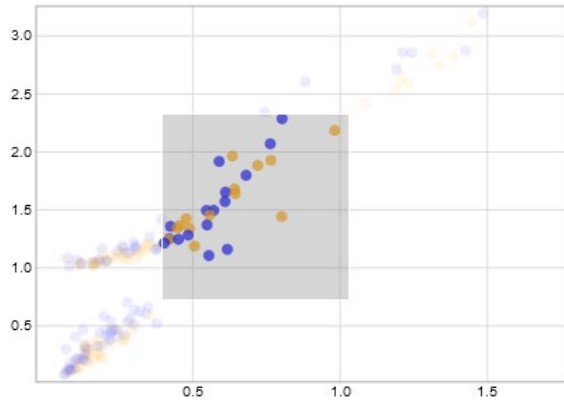


View interaction methods

- 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.

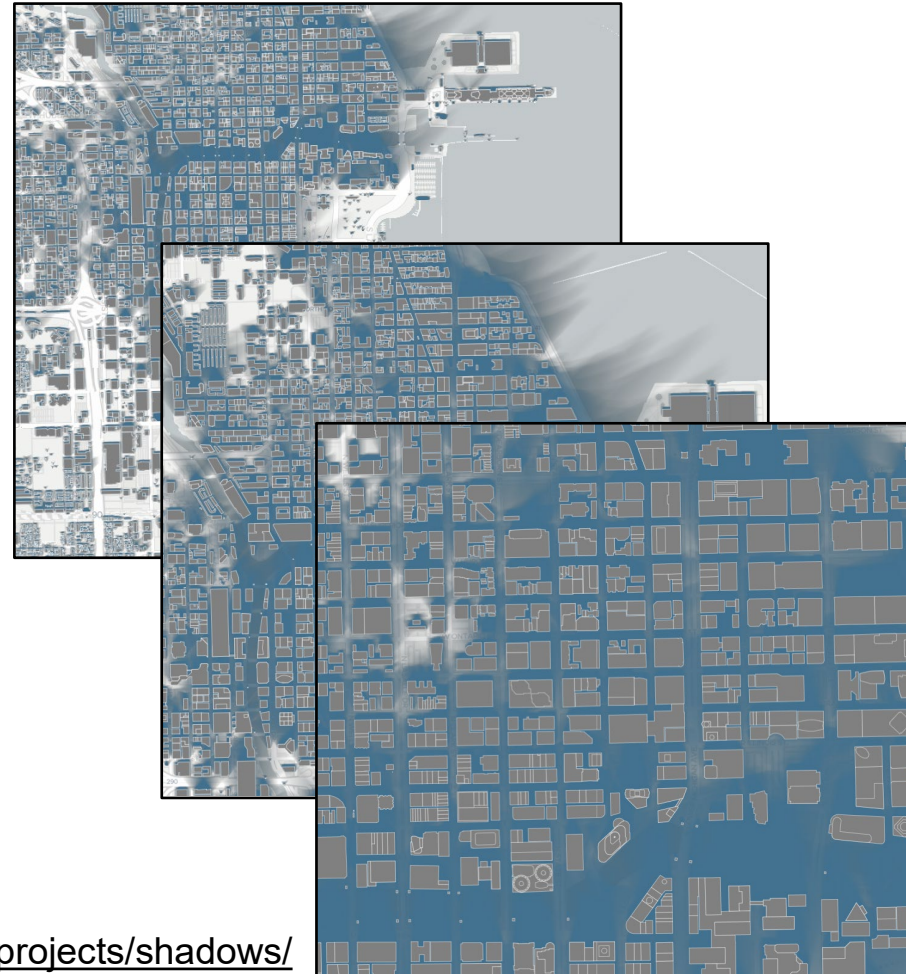
Manipulating the view

Selection



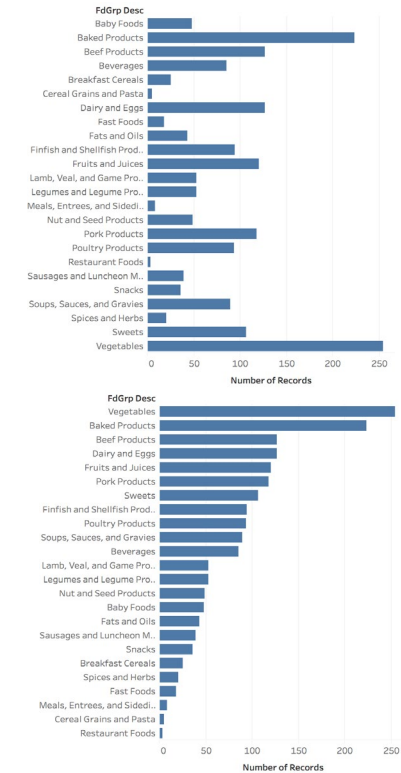
<https://vgc.poly.edu/projects/urban-pulse/>

Navigation



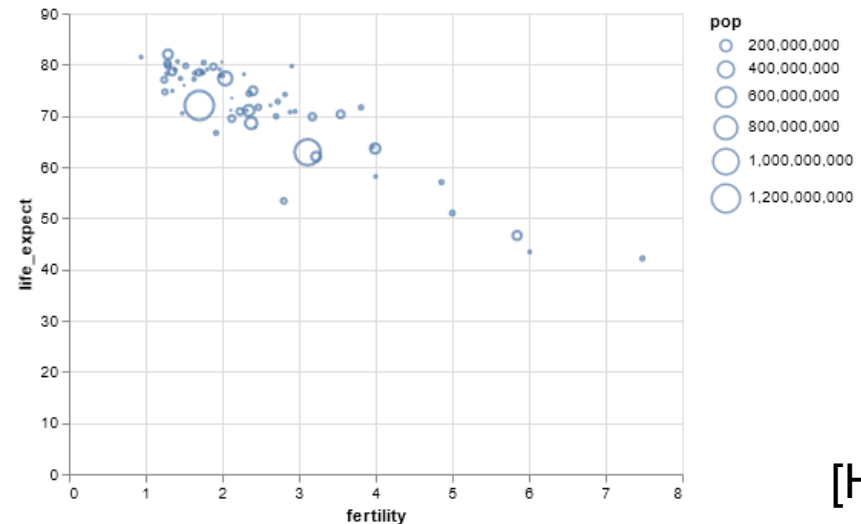
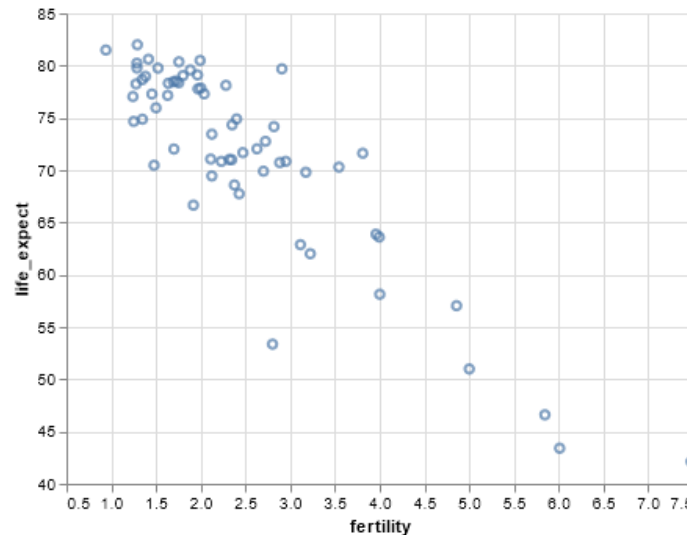
<https://vgc.poly.edu/projects/shadows/>

Spatial arrangement



Manipulating the visual mapping

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



[Heer, 2020]

Manipulating the visual mapping?

- Changing the color scale used to depict an attribute?
- Changing the order of bars in a bar chart?
- Filtering items that do not belong to a given category?

Manipulating the visual mapping?

- Changing the color scale used to depict an attribute?
 - True.
- Changing the order of bars in a bar chart?
 - False – order of the bars is a parameter of the graph, so it belongs to manipulation of the view.
- Filtering items that do not belong to a given category?
 - False – filtering is an action that takes place at the level of the data.

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.

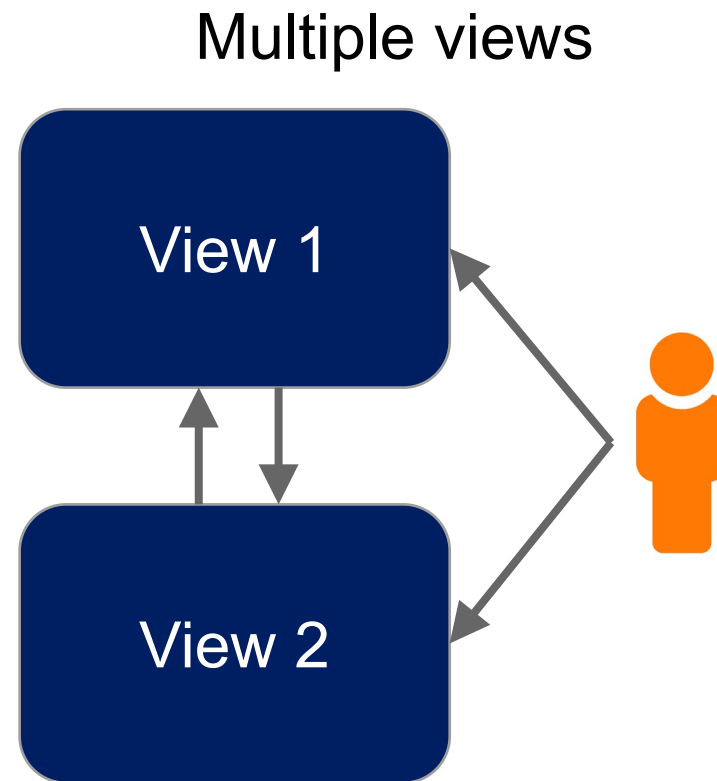
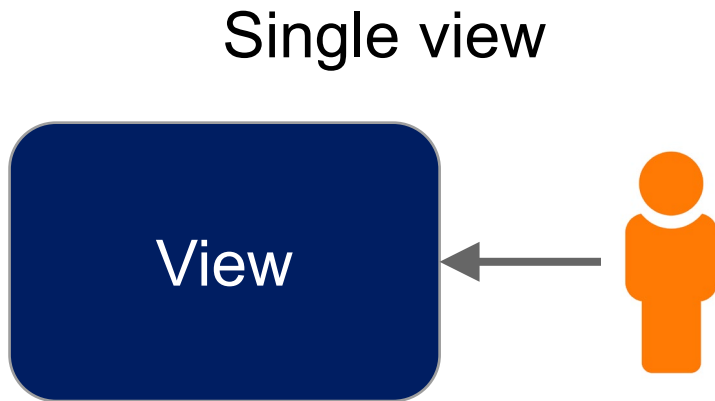
Why manipulate visualizations?

- It makes perceiving information faster?
- It permits to visualize more information that you can fit in one vis?
- It permits to ask multiple questions using the same vis?

Why manipulate visualizations?

- It makes perceiving information faster?
 - False – interaction may make answering questions slower.
- It permits to visualize more information that you can fit in one vis?
 - True.
- It permits to ask multiple questions using the same vis?
 - True.

Interaction



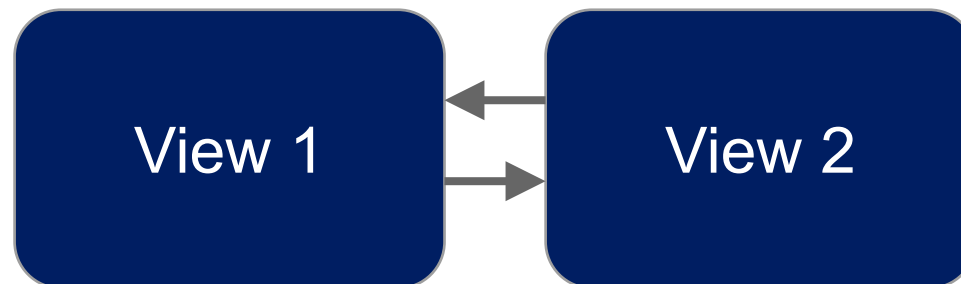
[Bertini, 2020]

Single view interactions

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

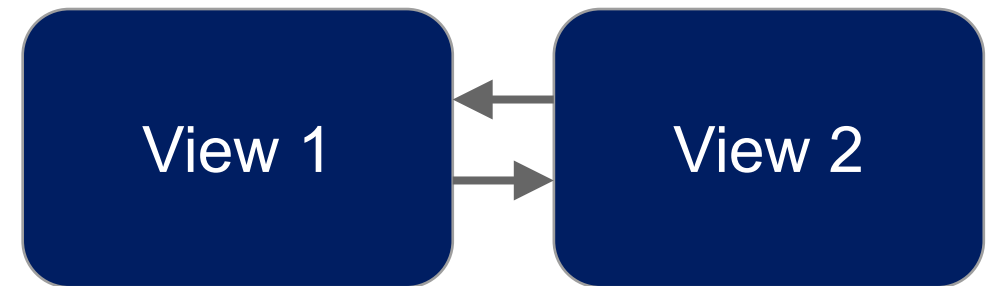
Multiple linked views

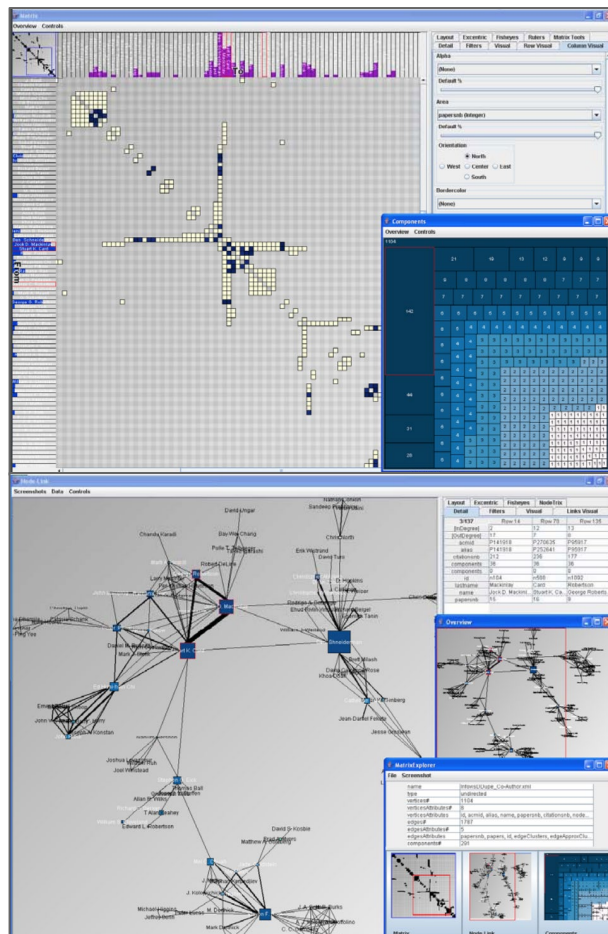
- Why multiple linked views?
 - Show different properties of the same data simultaneously.
 - Use one view to navigate, select, filter information in the other view.



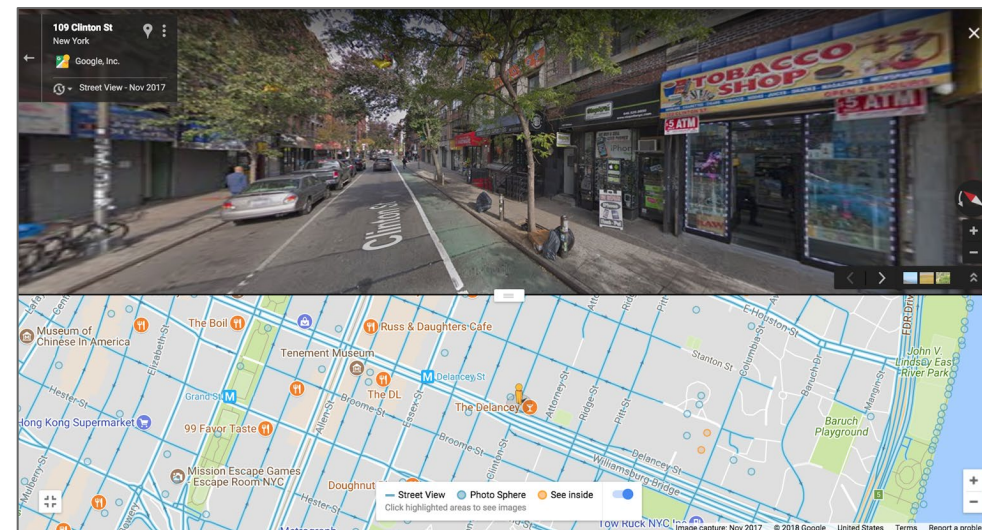
Multiple linked views

- How to show different properties?
 - Different information
 - Subset of data
 - Different attributes
 - Different granularity
 - Transformation
 - Different representation

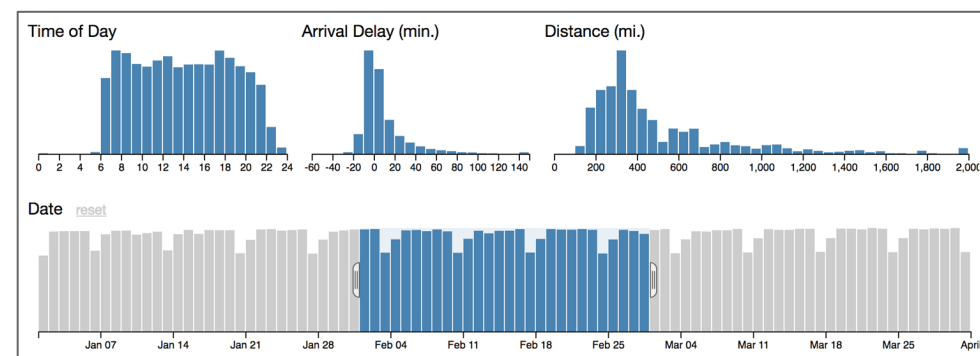




Same information,
different representation
[Riche, 2006]

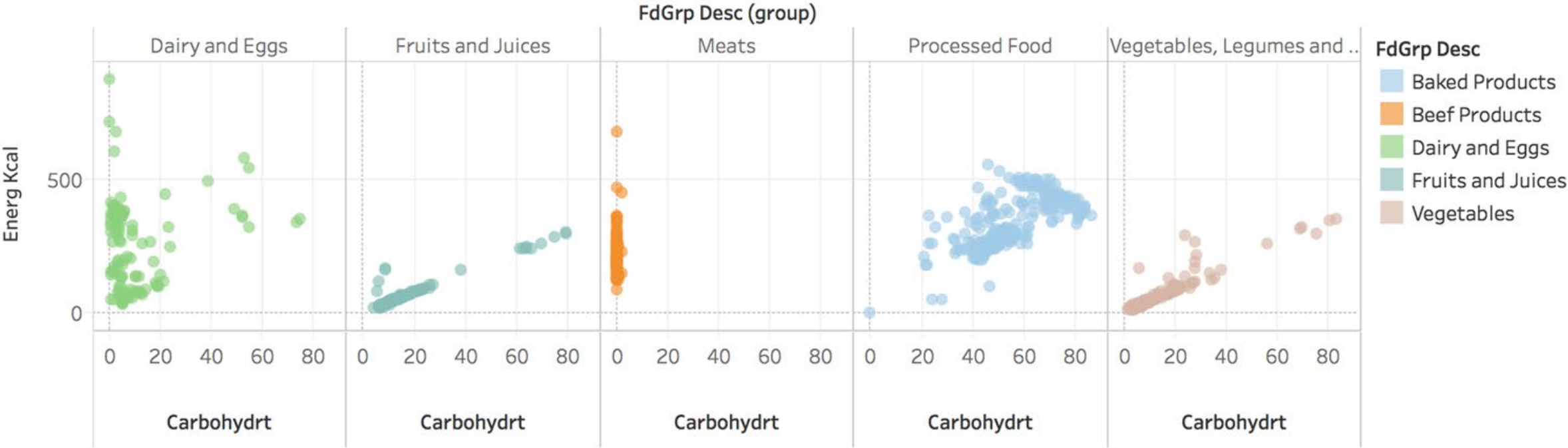


Different information & representation

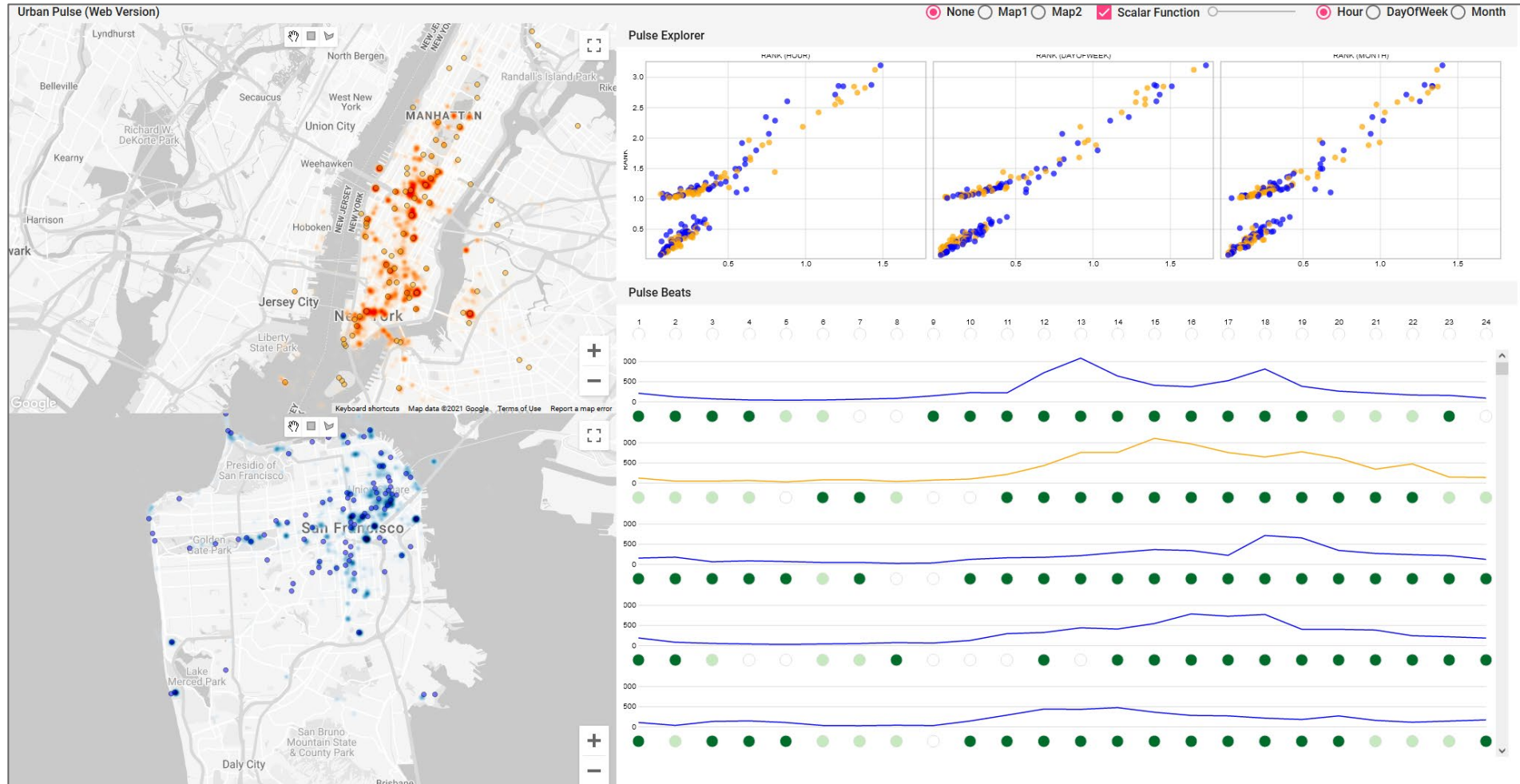


Different information,
same representation

Multiple linked views



Multiple linked views

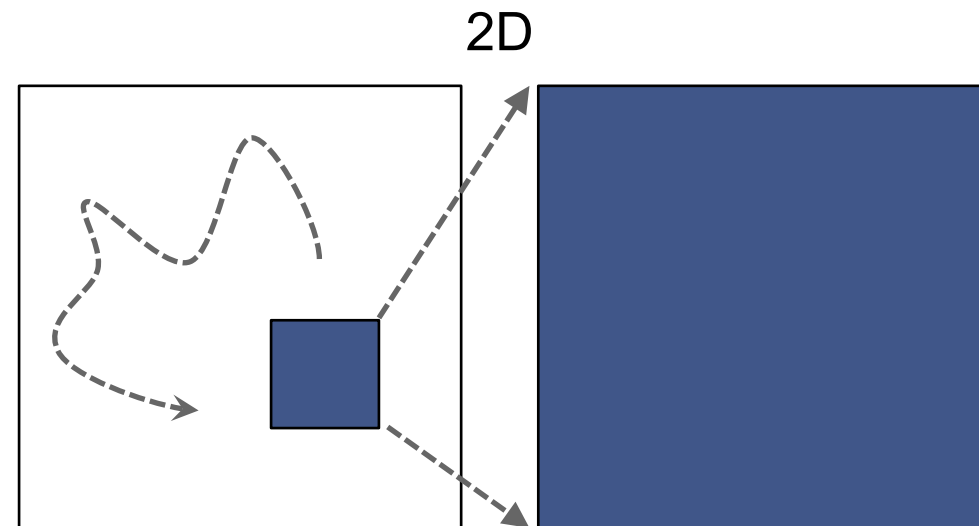
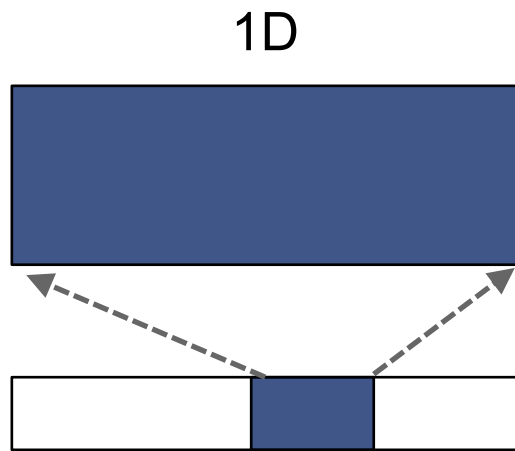


<http://vgc.poly.edu/projects/urban-pulse/>

Overview + detail

- Visualization mantra:
“Overview first, zoom and filter, then details on demand”

[Shneiderman, 1996]



Overview + detail



- **Ideal scenario**: can't fit all information on the screen without panning / scrolling.
- And why can panning and scrolling be a problem?
 - Hard to gain an overview.
 - Hard to make comparisons (it relies too heavily on human memory).

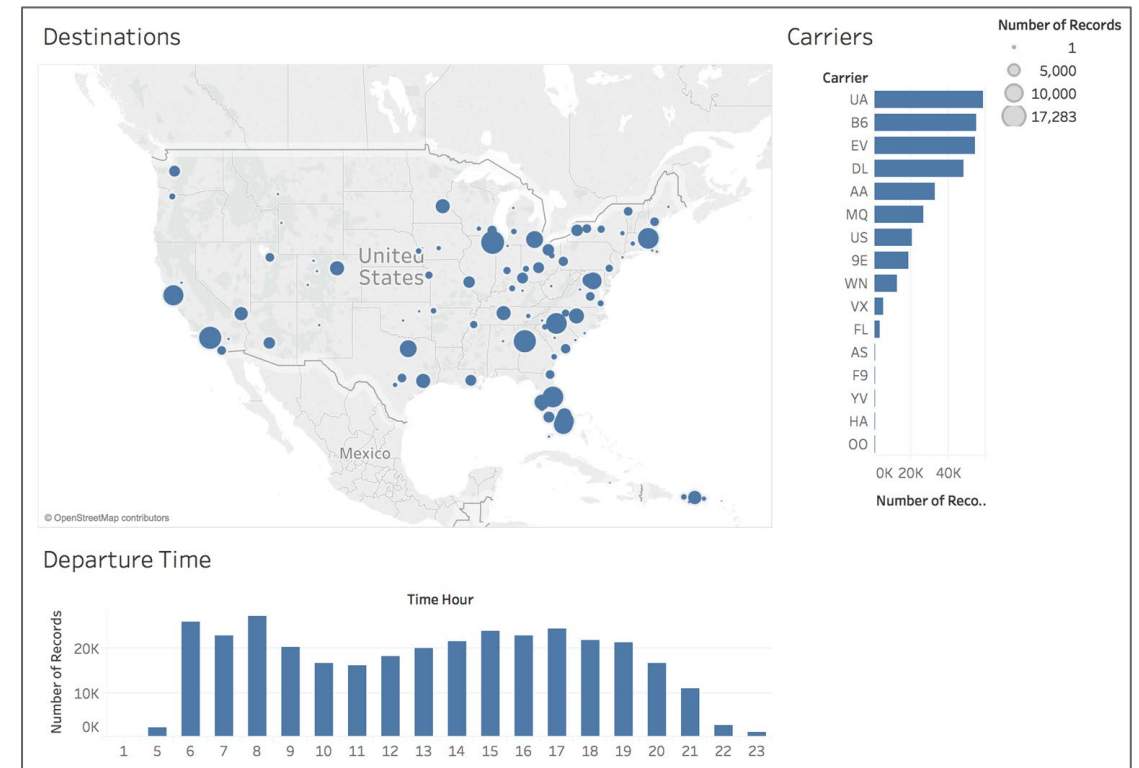
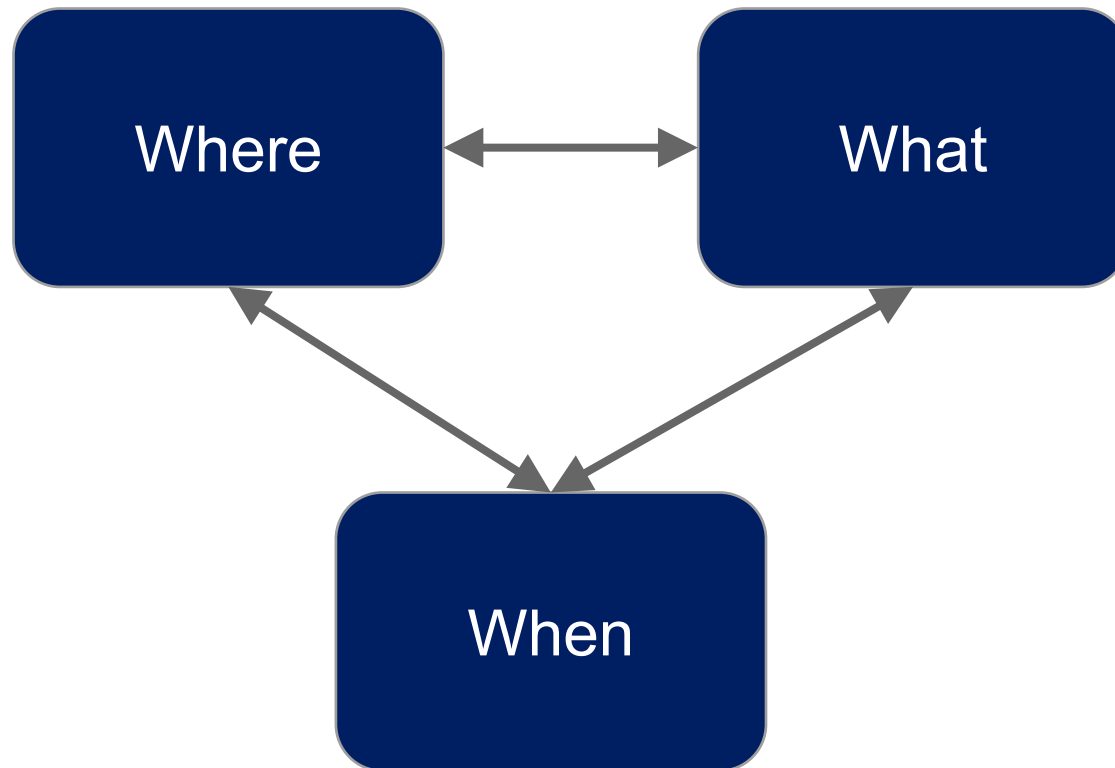
Overview + detail

- It is possible to use the overview to navigate towards areas of the visualization we want to see in detail without losing the overview of the entire dataset.
- It permits to visualize some objects at a much higher resolution.
- It permits to gain an overview of the whole dataset.

Overview + detail

- It is possible to use the overview to navigate towards areas of the visualization we want to see in detail without losing the overview of the entire dataset.
 - True.
- It permits to visualize some objects at a much higher resolution.
 - True, but other visualizations also permit that (e.g., zooming).
- It permits to gain an overview of the whole dataset.
 - True, but other views can also help gain an overview.

Where, what, when



Where, what, when

- **Ideal scenario**: need to visualize different facets of the same data simultaneously.



Visual query model

- Expressive Triad framework:
 - Where + when* → *what*: “What is the average trip time from Midtown to the airports during weekdays?”
 - When + what* → *where*: “Where are the hot spots in Manhattan in the weekends?”
 - Where + what* → *when*: “When were activities restored in Lower Manhattan after the Sandy hurricane?”

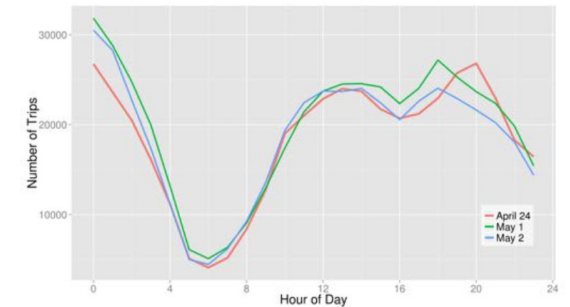
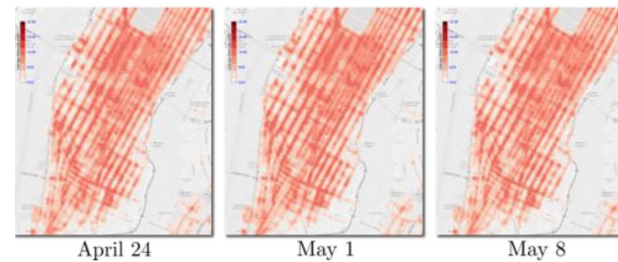
Where? When?
What?



Big data challenges

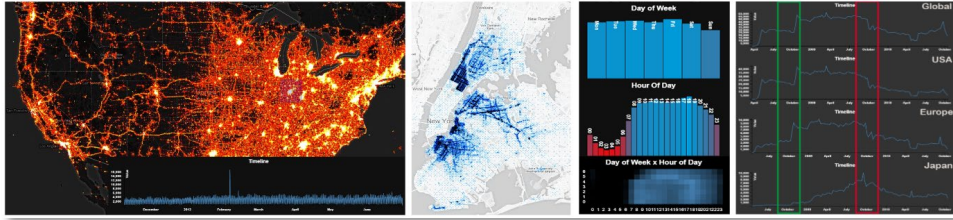


- 365×24 1-hour slices in one year.
- Which slides are interesting?

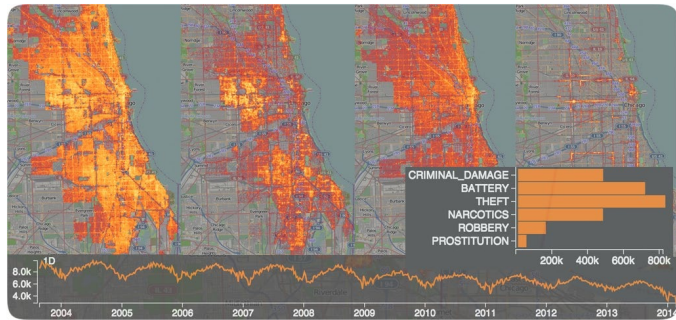


Accelerating data interaction methods

OLAP queries



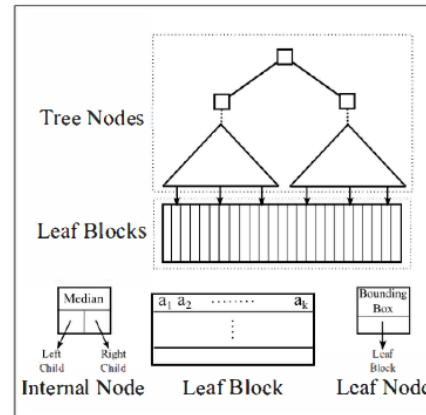
Hashedcubes [Pahins et al., 2017]



Nanocube [Lins et al., 2013]

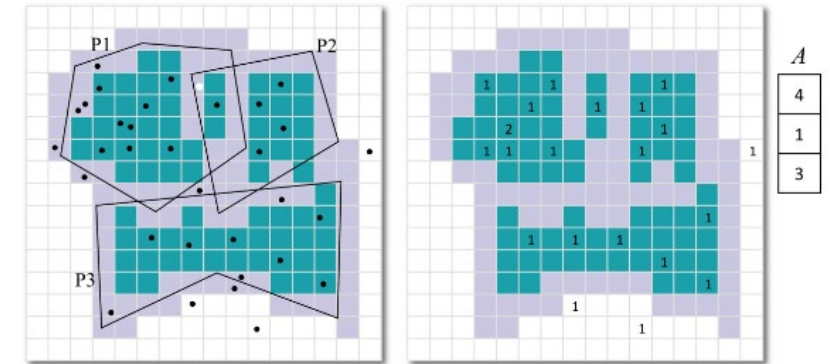
TopKube [Miranda et al., 2018]

Selection



STIG [Doraiswamy et al., 2015]

Spatiotemporal joins



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