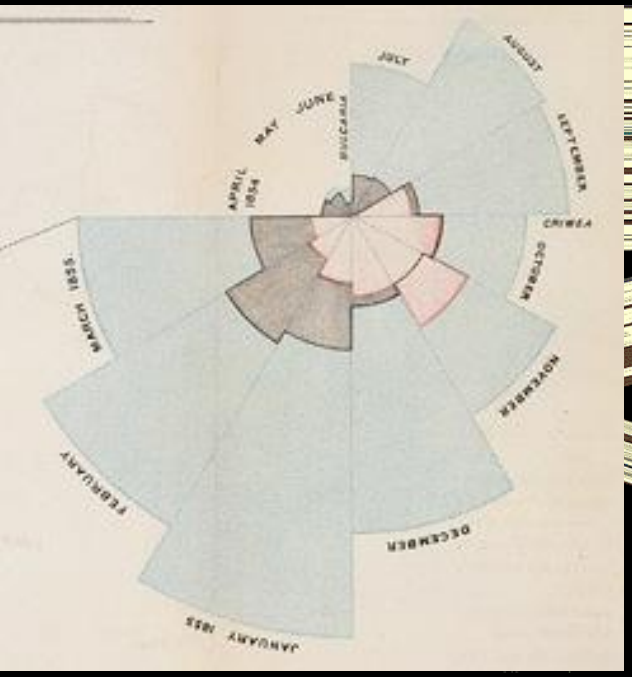
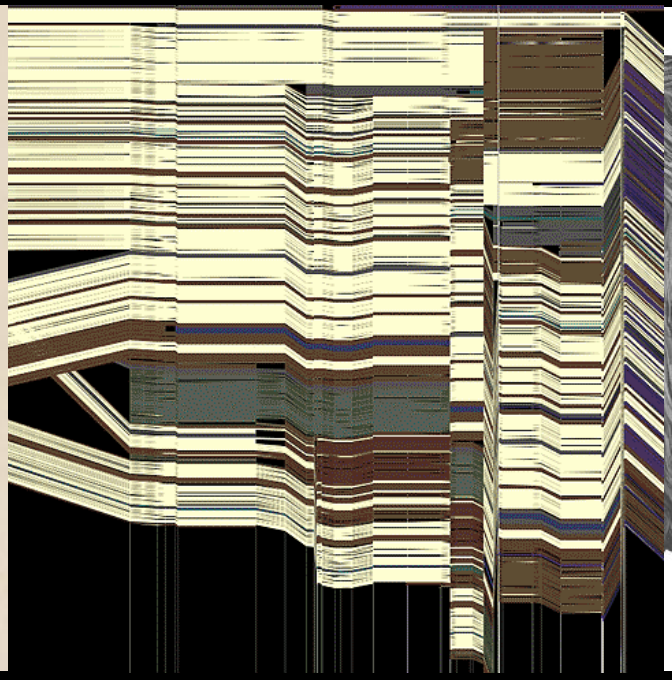
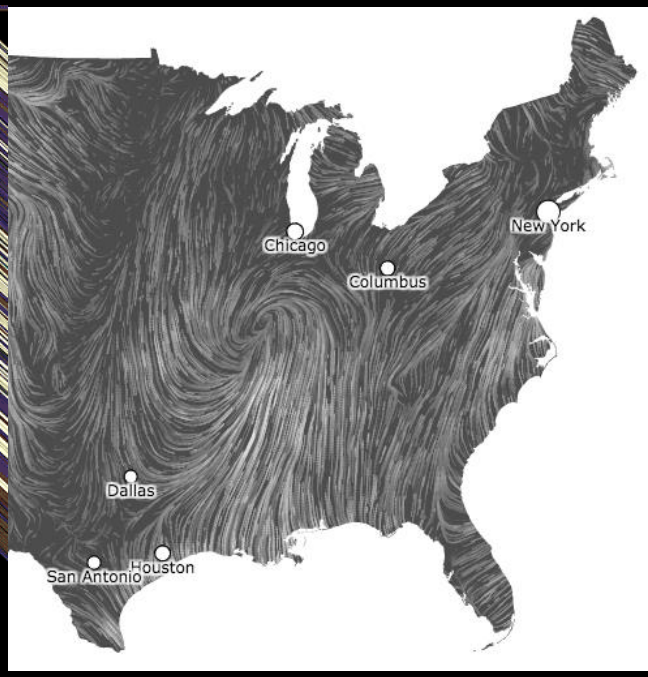
CSE 442 - Data Visualization

Interaction







Leilani Battle University of Washington

Learning Goals

What do we mean by “interaction”?

What role do interactions play in visualization?

What makes an interaction effective?

Topics

Effective Interactions

Interactive Visualization

Selection

Brushing & Linking

Dynamic Queries

Prompting Reflection

Vega-Lite Selections

Exercise: What is an Interaction?

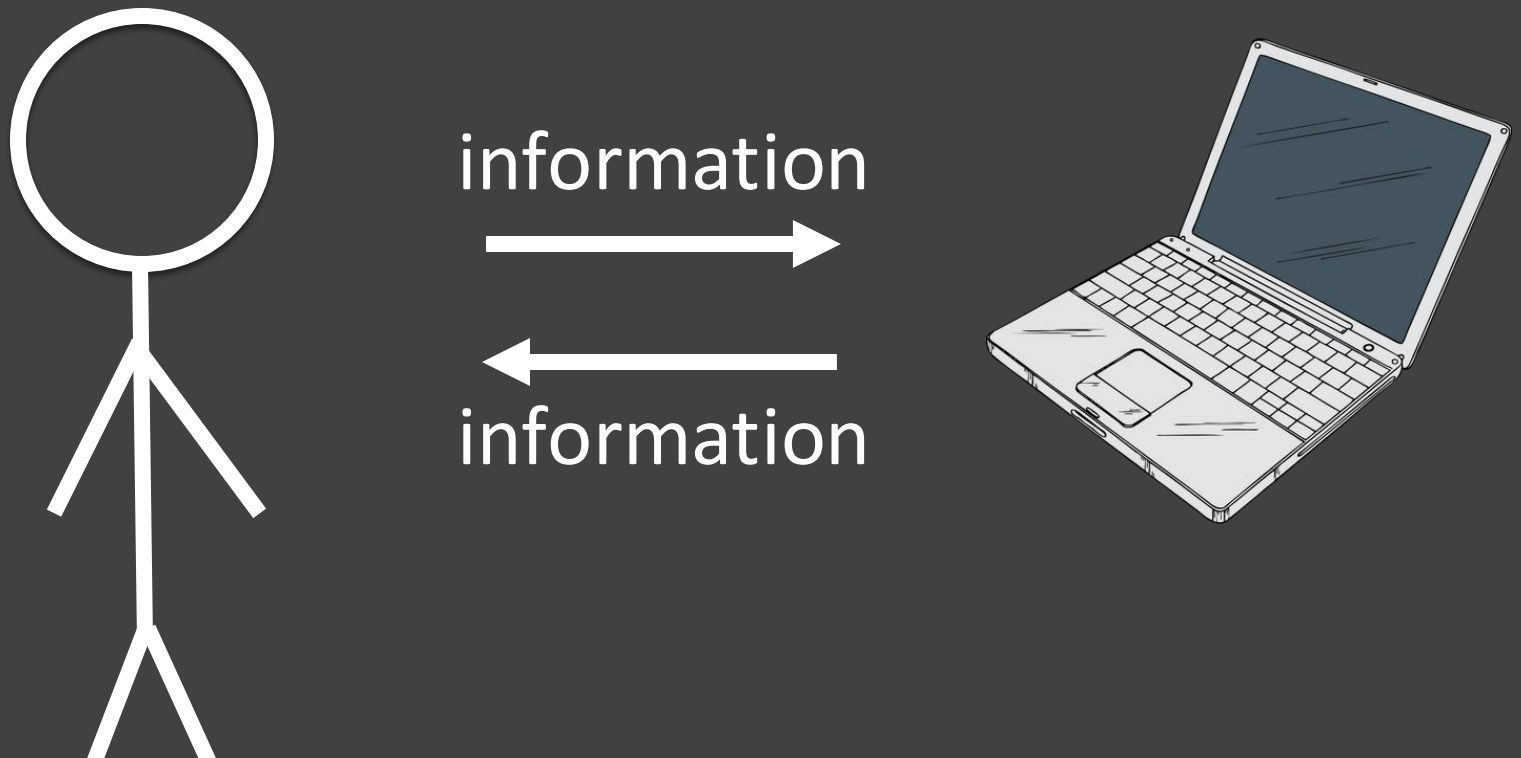
How would you define interactions in your own words?

[There is an] apparent challenge that computational artifacts pose to the longstanding distinction between the physical and the social, in the special sense of those things that one designs, builds, and uses, on the one hand, and those things with which one communicates, on the other.

"Interaction"– in a sense previously reserved for describing a uniquely interpersonal activity – seems appropriately to characterize what goes on between people and certain machines as well.

Lucy Suchman, *Plans and Situated Actions*

Interaction between people and machines requires *mutual intelligibility* or *shared understanding*.



Gulfs of Execution & Evaluation

Conceptual model

Gulfs

Real world

Evaluation

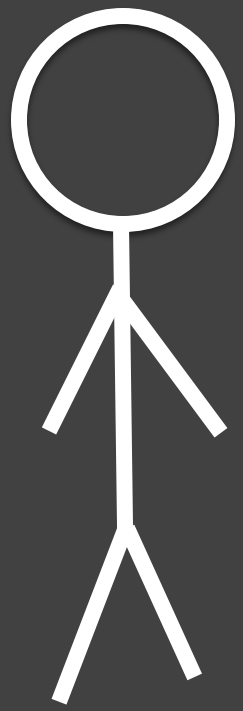
X	Y
0.67	0.79
0.32	0.63
0.39	0.72
0.27	0.85
0.71	0.43
3	0.09
3	0.03
0	0.54
1	0.38
1	0.33
6	0.46

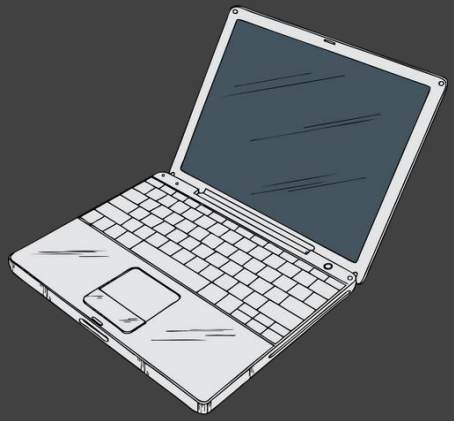
Execution

[Norman 1986]

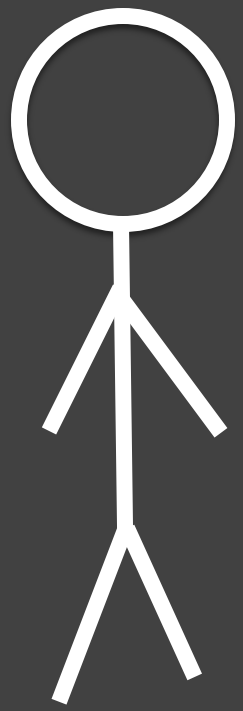
Gulf of Execution

The difference between the user's intentions and the allowable actions.





[Norman 1986]



Gulf of Execution

The difference between the user's intentions and the allowable actions.

Gulf of Evaluation

The amount of effort that the person must exert to interpret the state of the system and to determine how well the expectations and intentions have been met.

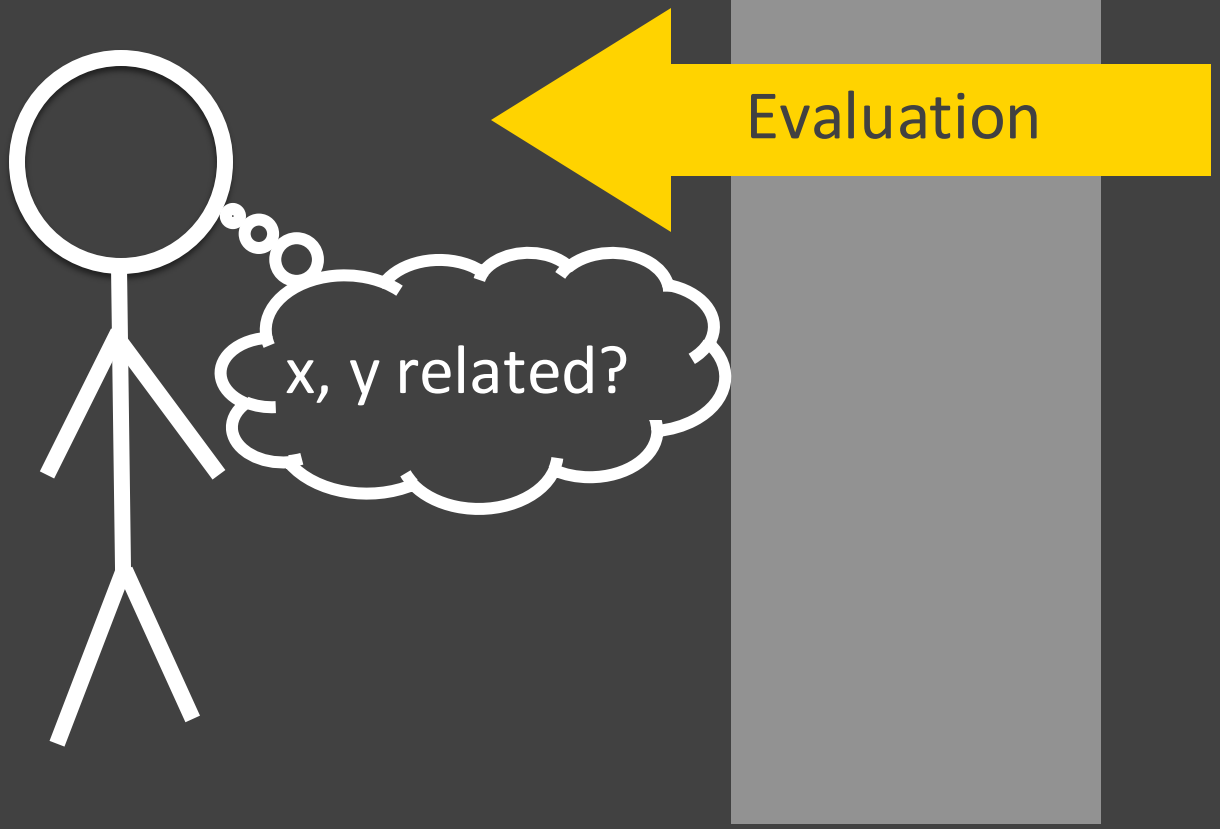
[Norman 1986]

Gulf of Evaluation

Gulf

Conceptual model

Real world:



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0.51	0.38
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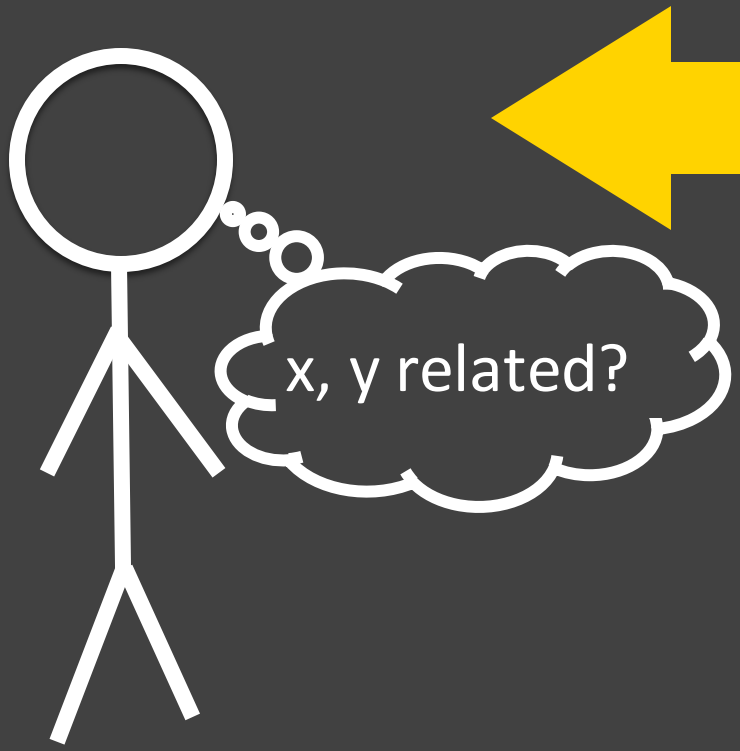
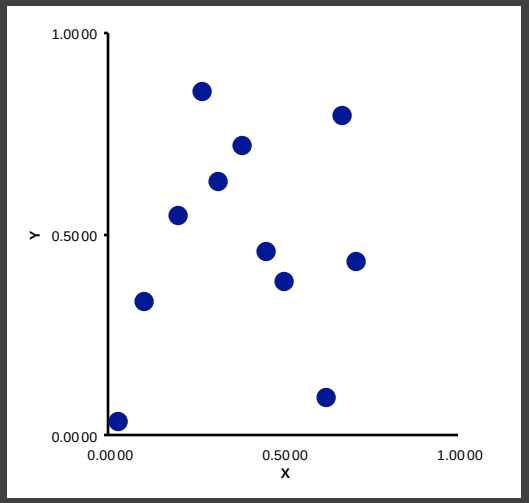
Gulf of Evaluation

Gulf

Conceptual model

Real world:



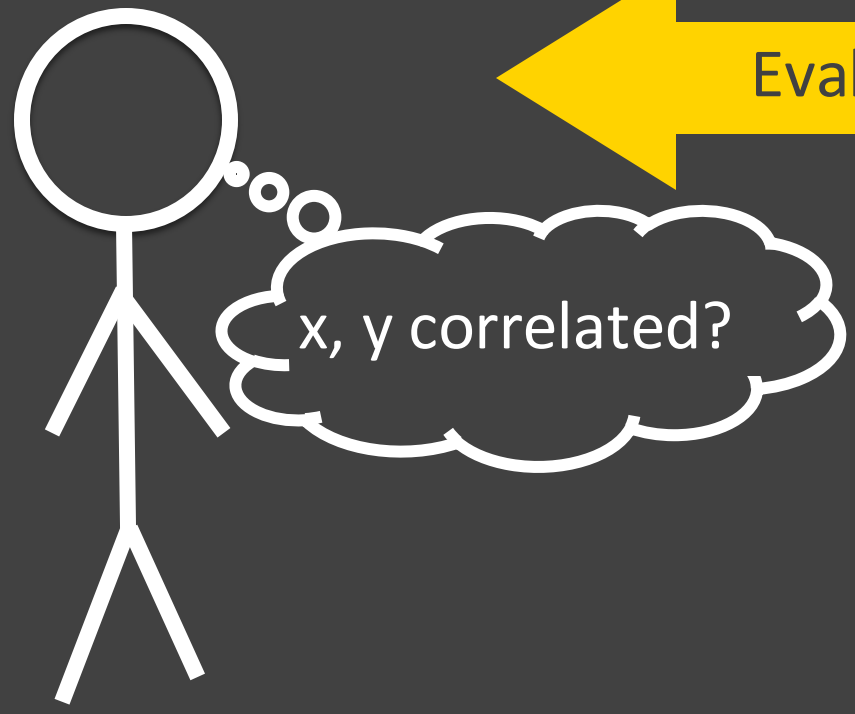


Gulf of Evaluation

Gulf

Conceptual model

Real world:

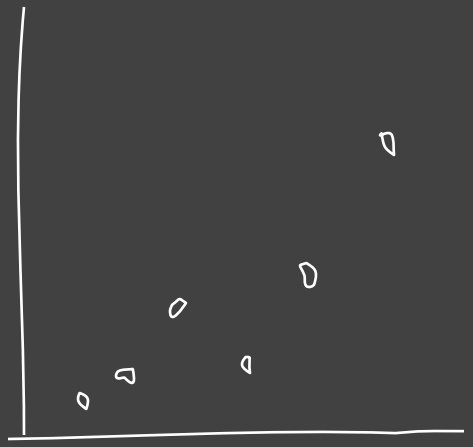


$\rho = -.29$

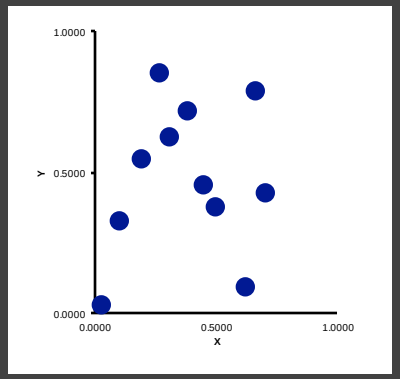
Gulf of Execution

Gulf

Conceptual model:
Draw a scatterplot



Execution



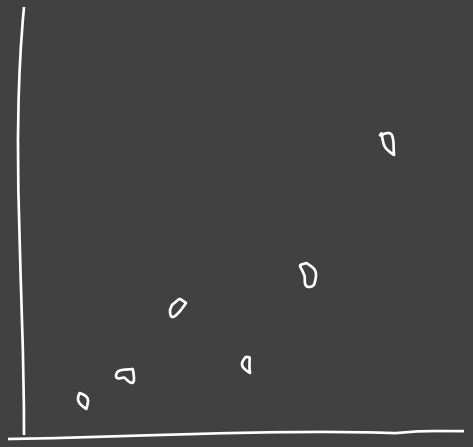
Real world

Move 90 30
Rotate 35
Pen down
…

Gulf of Execution

Gulf

Conceptual model:
Draw a scatterplot



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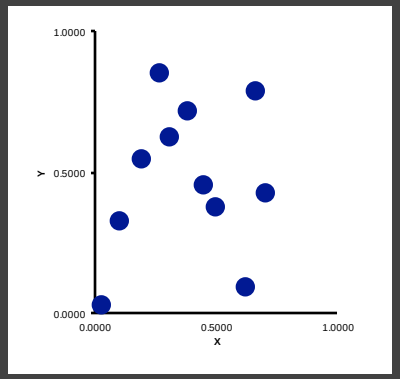


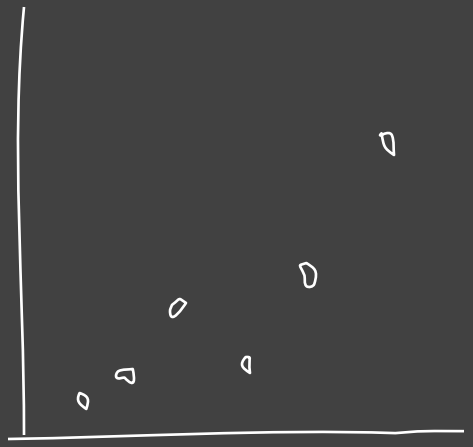
Real world

```
vl.markCircle()
  .encode(
    vl.x().fieldQ(...),
    vl.y().fieldQ(...)
  )
```

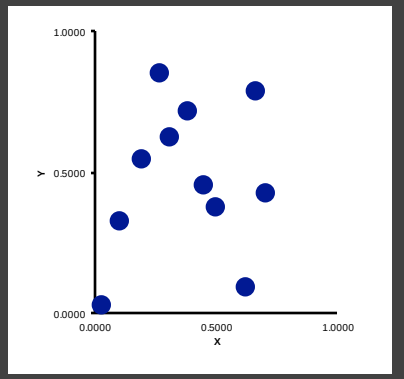
Gulf of Execution

Gulf

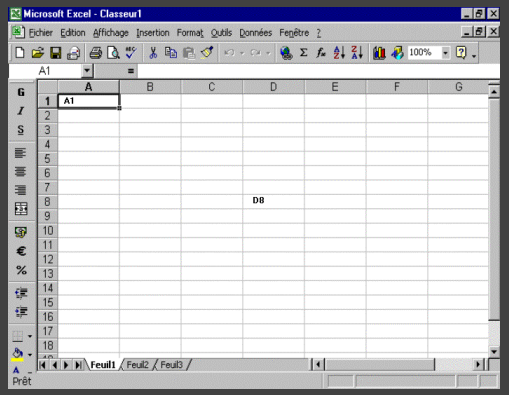
Conceptual model:
Draw a scatterplot

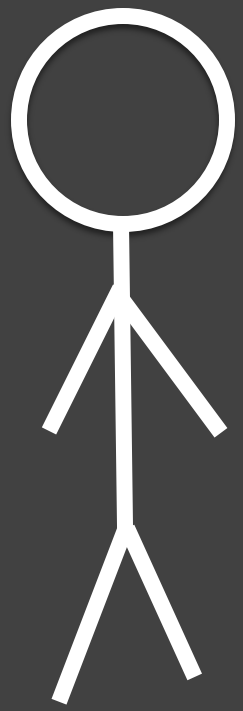


Execution



Real world





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[Norman 1986]

Significance for Visualization

Good interactions:

- Empower people to answer their own questions about the data (execution)
- Generate results that are easy for people to interpret (evaluation)

Interactive Visualization

Interaction Techniques

Are there “essential” interactive operations for exploratory data visualization?

Taxonomy of Interactions

Taxonomy of Interactions

Data and View Specification
Visualize, Filter, Sort, Derive

Tableau - Book1

Normal | Show Me

Data | Analytics

Sample – Superstore

Dimensions

- Customer
  - Customer Name
  - Segment
- Order
- Location
- Product
  - Category
  - Sub-Category
  - Manufacturer
  - Product Name
- Profit (bin)
- Region
- *Measure Names*

Measures

- Discount
- Profit
- Profit Ratio
- Quantity
- Sales
- *Latitude (generated)*
- *Longitude (generated)*
- *Number of Records*
- *Measure Values*

Pages

Filters

Marks

Automatic

Color | Size | Label | Detail | Tooltip

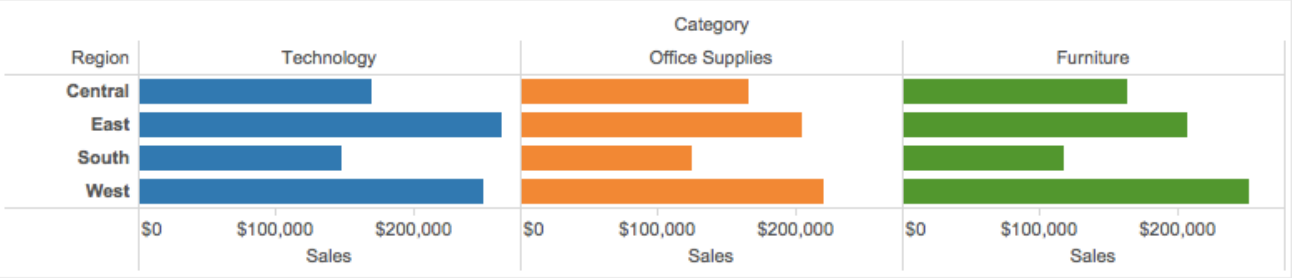
Category

Category

- Technology
- Office Supplies
- Furniture

Columns: Category | SUM(Sales)

Rows: Region



Data Source | Sheet 1

12 marks | 4 rows by 3 columns | SUM(Sales): $2,297,201

Tableau - Book1

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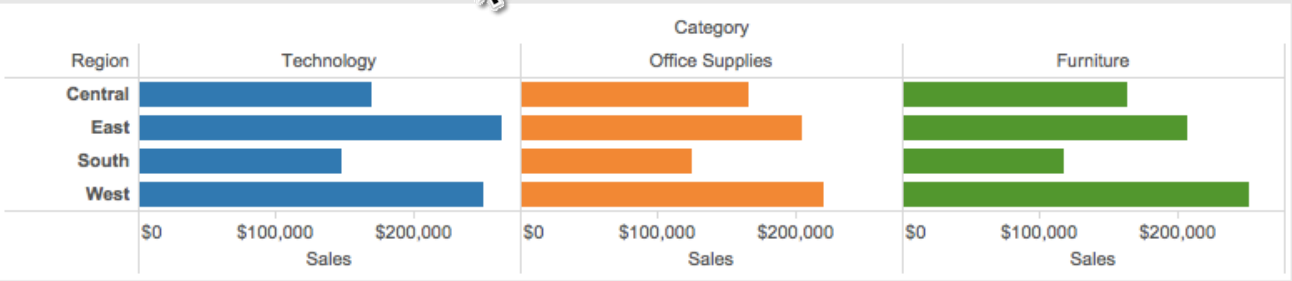

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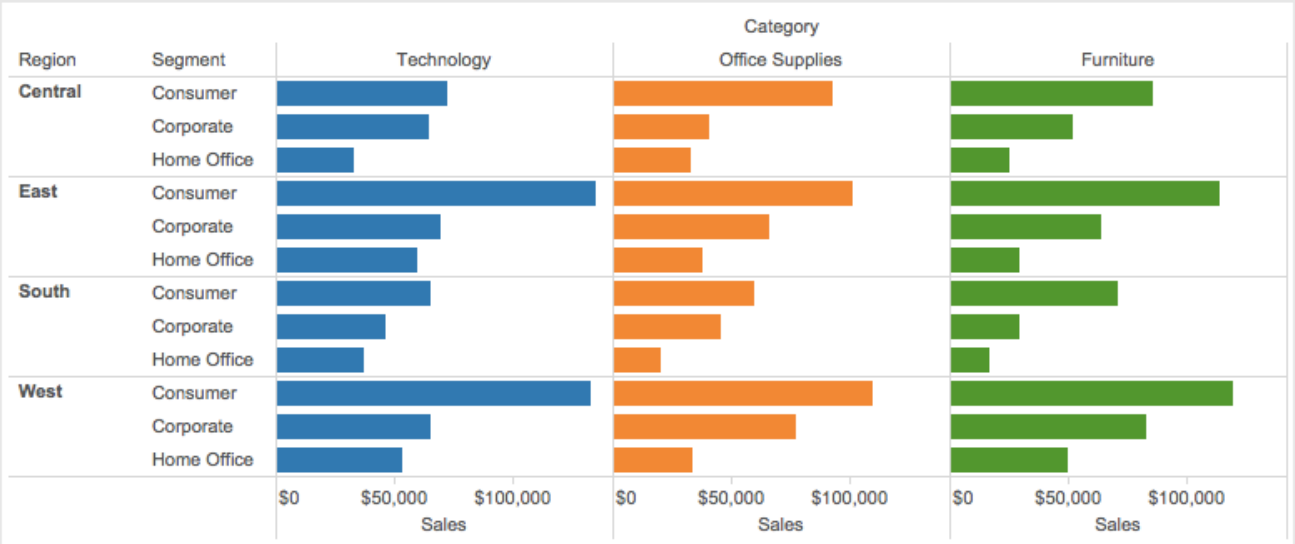

Data Source | Sheet 1

36 marks | 12 rows by 3 columns | SUM(Sales): $2,297,201

Tableau - Book1

Normal | Show Me

Data | Analytics

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  - Segment
- Order
- Location
- Product
  - Category
  - Sub-Category
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  - Product Name
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- Region
- *Measure Names*

Measures

- Discount
- Profit
- Profit Ratio
- Quantity
- Sales
- *Latitude (generated)*
- *Longitude (generated)*
- *Number of Records*
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Pages

Filters

Marks

Automatic

Color | Size | Label | Detail | Tooltip

Category

Category

- Technology
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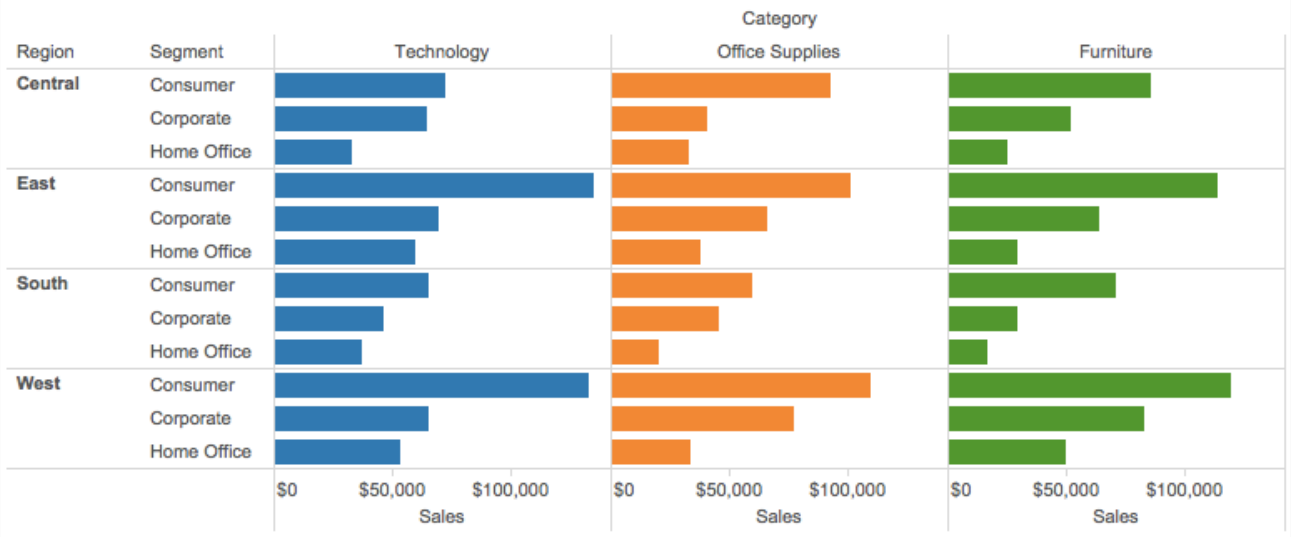
Columns: Category | SUM(Sales)

Rows: Region | Segment



Data Source | Sheet 1

36 marks | 12 rows by 3 columns | SUM(Sales): $2,297,201

Tableau - Book1

Normal

Show Me

Data | Analytics

Sample – Superstore

Dimensions

- Customer
  - Customer Name
  - Segment
- Order
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- Product
  - Category
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  - Manufacturer
  - Product Name
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- Region
- *Measure Names*

Measures

- Discount
- Profit
- Profit Ratio
- Quantity
- Sales
- *Latitude (generated)*
- *Longitude (generated)*
- *Number of Records*
- *Measure Values*

Pages

Filters

Marks

All

Automatic

Color | Size | Label | Detail | Tooltip

Category

SUM(Sales)

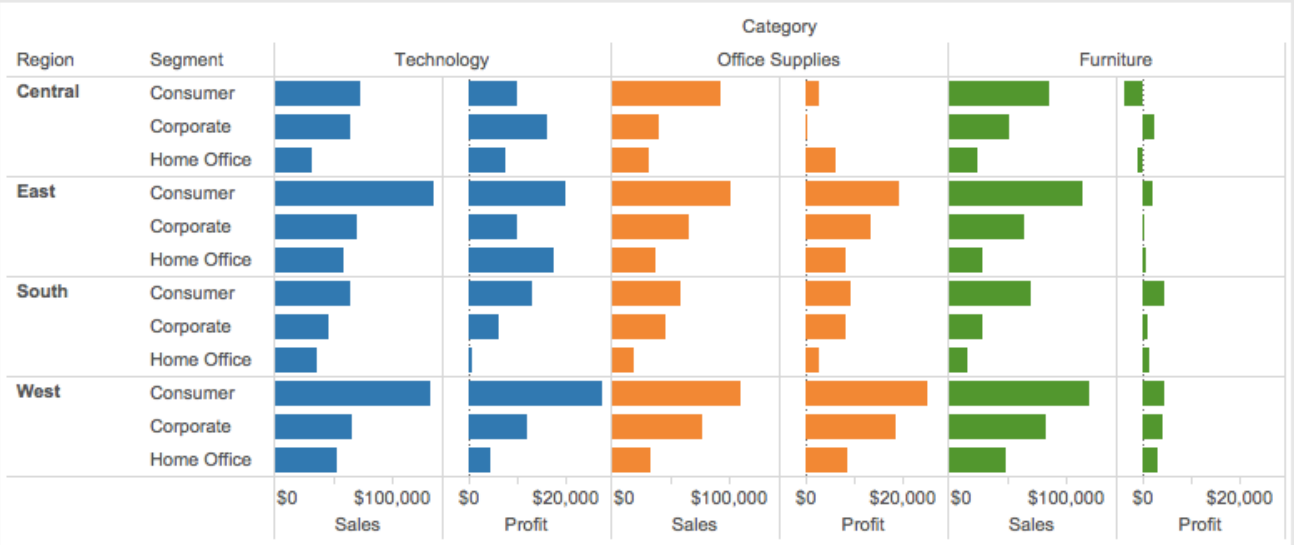
SUM(Profit)

Category

- Technology
- Office Supplies
- Furniture

Columns: Category | SUM(Sales) | SUM(Profit)

Rows: Region | Segment



Data Source | Sheet 1

72 marks | 12 rows by 6 columns | SUM(Profit): $286,397

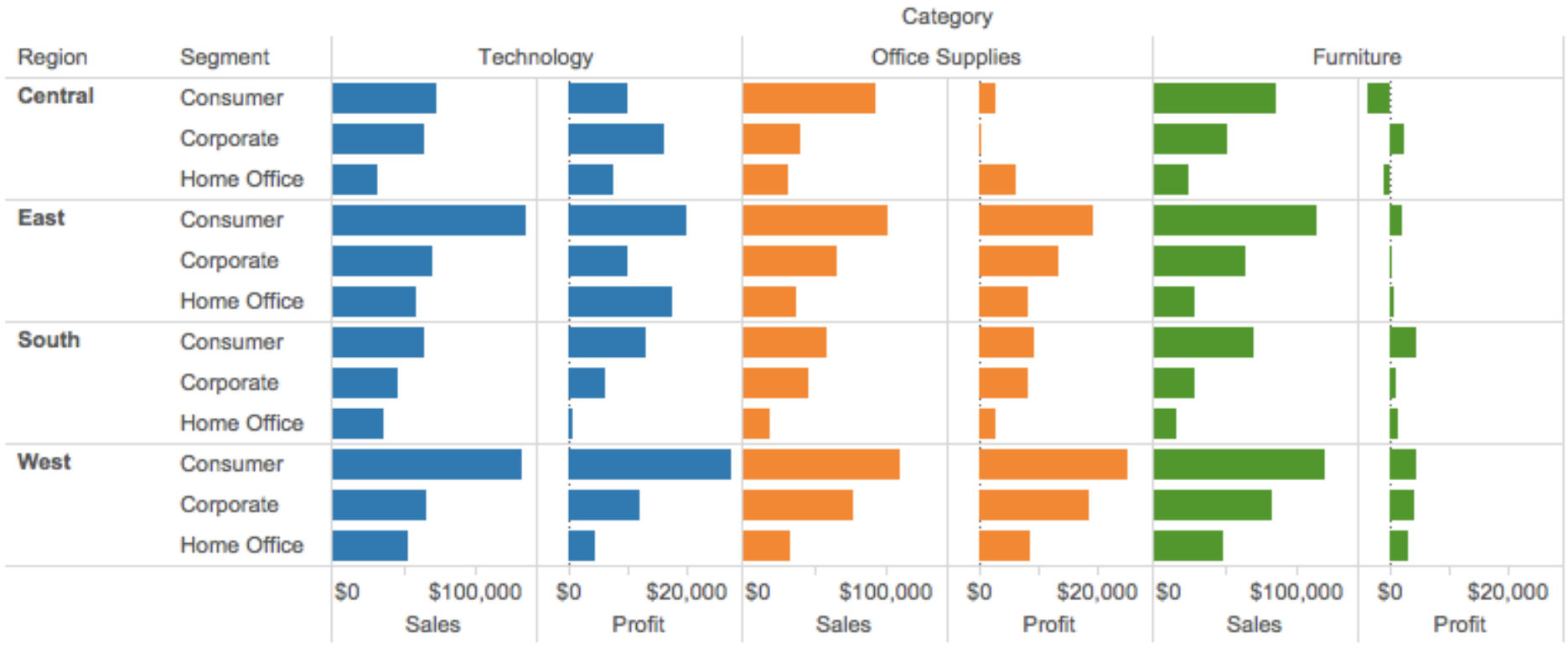
Tableau - Book1

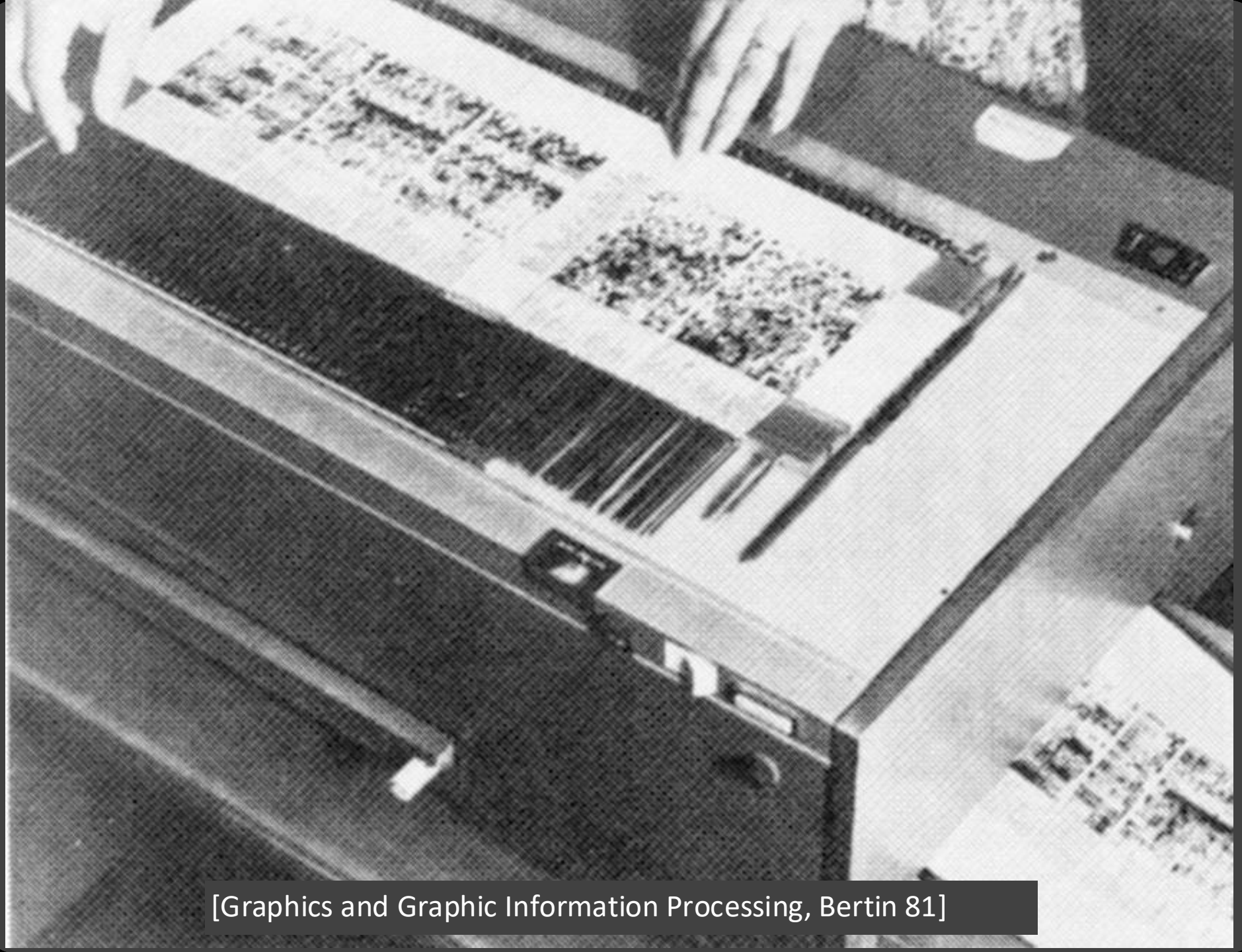
Normal

Show Me

Columns: Category, SUM(Sales), SUM(Profit)

Rows: Region, Segment





[Graphics and Graphic Information Processing, Bertin 81]

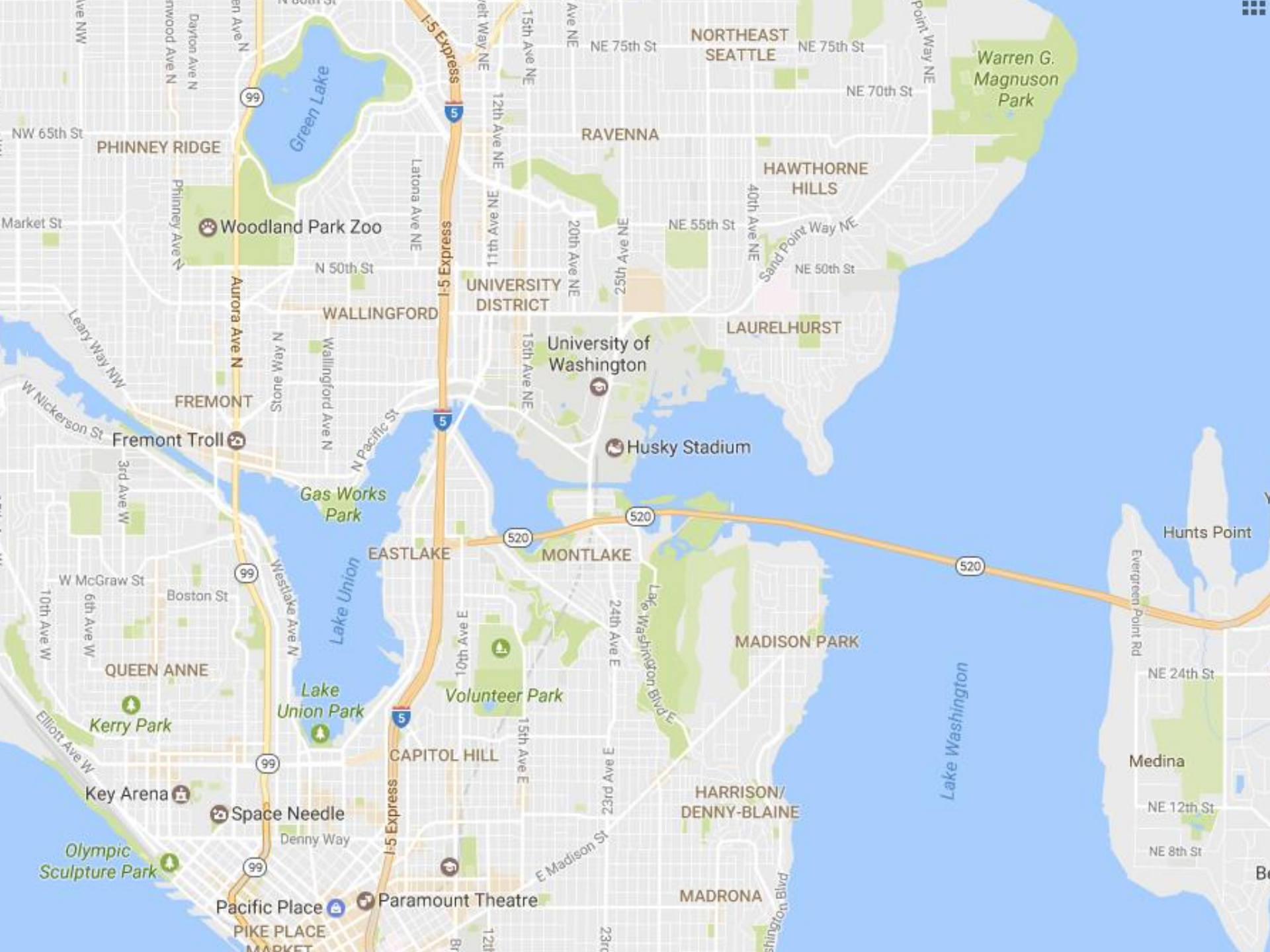
Taxonomy of Interactions

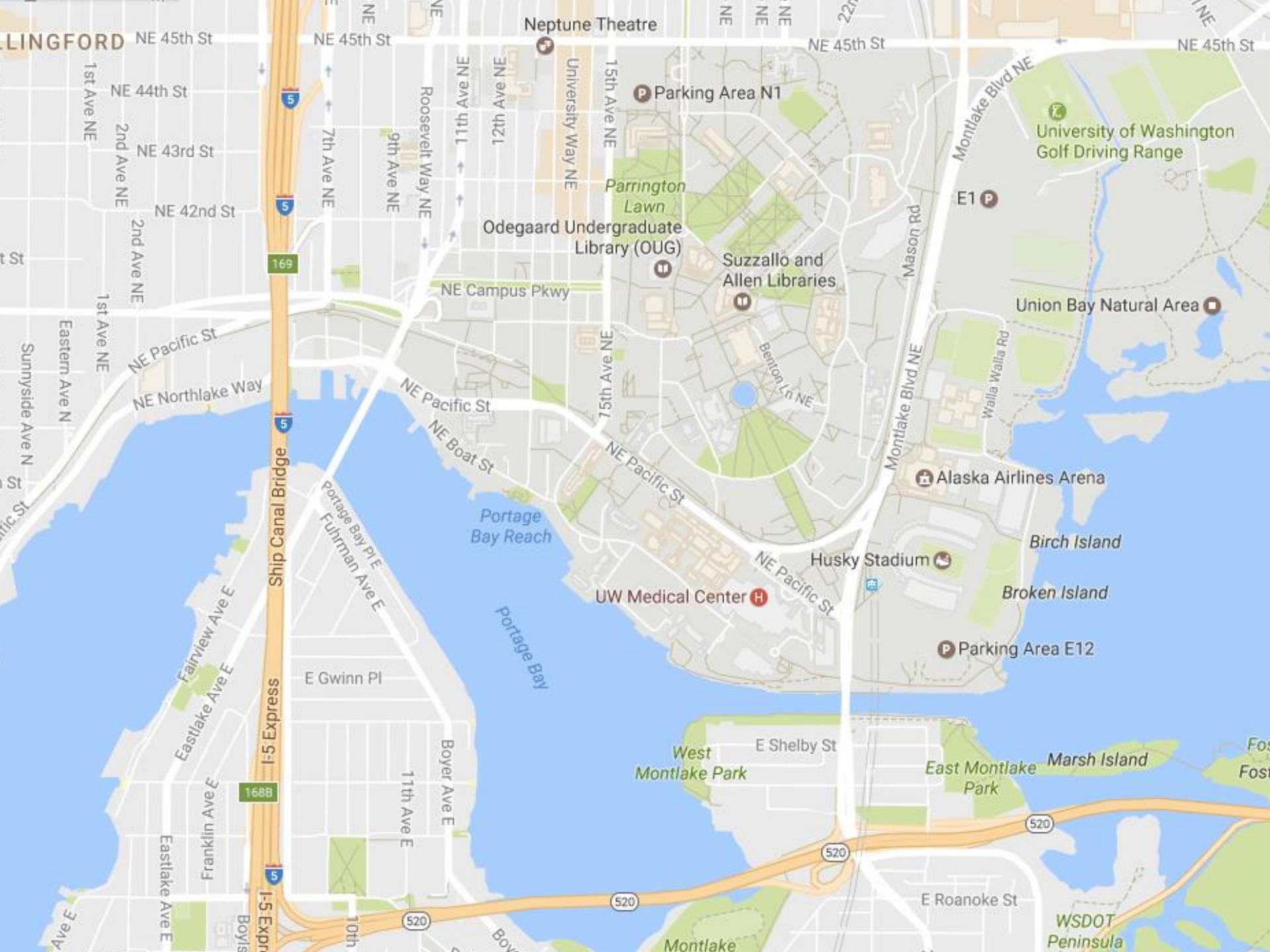
Data and View Specification
Visualize, Filter, Sort, Derive

Taxonomy of Interactions

Data and View Specification
Visualize, Filter, Sort, Derive

View Manipulation
Select, Navigate, Coordinate, Organize


NORTHEAST SEATTLE
NE 75th St
NE 70th St
Warren G. Magnuson Park
Green Lake
RAVENNA
PHINNEY RIDGE
NW 65th St
HAWTHORNE HILLS
Woodland Park Zoo
Market St
NE 55th St
N 50th St
NE 50th St
UNIVERSITY DISTRICT
WALLINGFORD
LAURELHURST
University of Washington
FREMONT
Fremont Troll
Husky Stadium
Gas Works Park
EASTLAKE
MONTLAKE
Hunts Point
Lake Union
MADISON PARK
QUEEN ANNE
Lake Union Park
Volunteer Park
Kerry Park
CAPITOL HILL
Medina
Key Arena
Space Needle
HARRISON/ DENNY-BLAINE
Lake Washington
Olympic Sculpture Park
Denny Way
Pacific Place
Paramount Theatre
MADRONA
PIKE PLACE
Aurora Ave N
I-5 Express
Latona Ave NE
12th Ave NE
15th Ave NE
20th Ave NE
25th Ave NE
40th Ave NE
Sand Point Way NE
Leary Way NW
W Nickerson St
N Pacific St
Stone Way N
Wallingford Ave N
3rd Ave W
W McGraw St
Boston St
Westlake Ave N
10th Ave W
6th Ave W
Elliott Ave W
10th Ave E
15th Ave E
24th Ave E
Lake Washington Blvd E
23rd Ave E
E Madison St
Evergreen Point Rd
NE 24th St
NE 12th St
NE 8th St
520
99
5


LLINGFORD
NE 45th St
NE 45th St
Neptune Theatre
NE 45th St
NE 45th St
1st Ave NE
NE 44th St
2nd Ave NE
NE 43rd St
NE 42nd St
2nd Ave NE
1st Ave NE
7th Ave NE
9th Ave NE
Roosevelt Way NE
11th Ave NE
12th Ave NE
University Way NE
15th Ave NE
Parking Area N1
Parrington Lawn
Odegaard Undergraduate Library (OUG)
Suzzallo and Allen Libraries
NE Campus Pkwy
Mason Rd
Montlake Blvd NE
University of Washington Golf Driving Range
E1
Union Bay Natural Area
Benton Ln NE
Walla Walla Rd
Montlake Blvd NE
Sunnyside Ave N
Eastern Ave N
1st Ave NE
NE Pacific St
NE Northlake Way
NE Pacific St
NE Boat St
15th Ave NE
NE Pacific St
Alaska Airlines Arena
Ship Canal Bridge
Portage Bay Reach
Portage Bay Pl E
Fuhrman Ave E
Birch Island
Husky Stadium
NE Pacific St
Broken Island
UW Medical Center
Portage Bay
Fairview Ave E
Eastlake Ave E
I-5 Express
E Gwinn Pl
Parking Area E12
E Shelby St
West Montlake Park
East Montlake Park
Marsh Island
Boyer Ave E
11th Ave E
Franklin Ave E
Eastlake Ave E
I-5 Express
520
520
520
E Roanoke St
WSDOT Peninsula
Montlake
10th
169
168B
5

Taxonomy of Interactions

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Visualize, Filter, Sort, Derive

View Manipulation
Select, Navigate, Coordinate, Organize

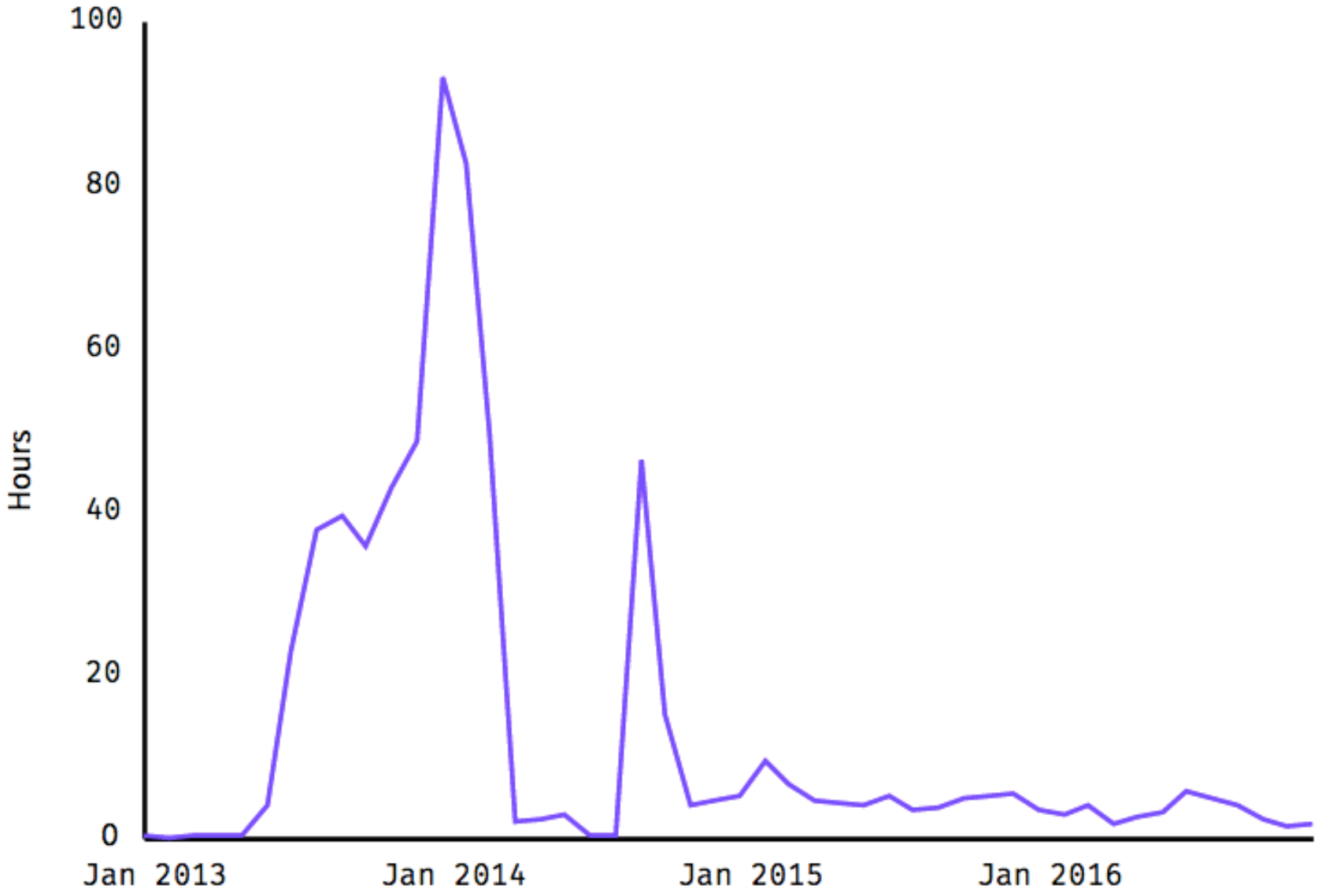
Taxonomy of Interactions

Data and View Specification
Visualize, Filter, Sort, Derive

View Manipulation
Select, Navigate, Coordinate, Organize

Process and Provenance
Record, Annotate, Share, Guide

Hours of footage lost each month due to dropped frames



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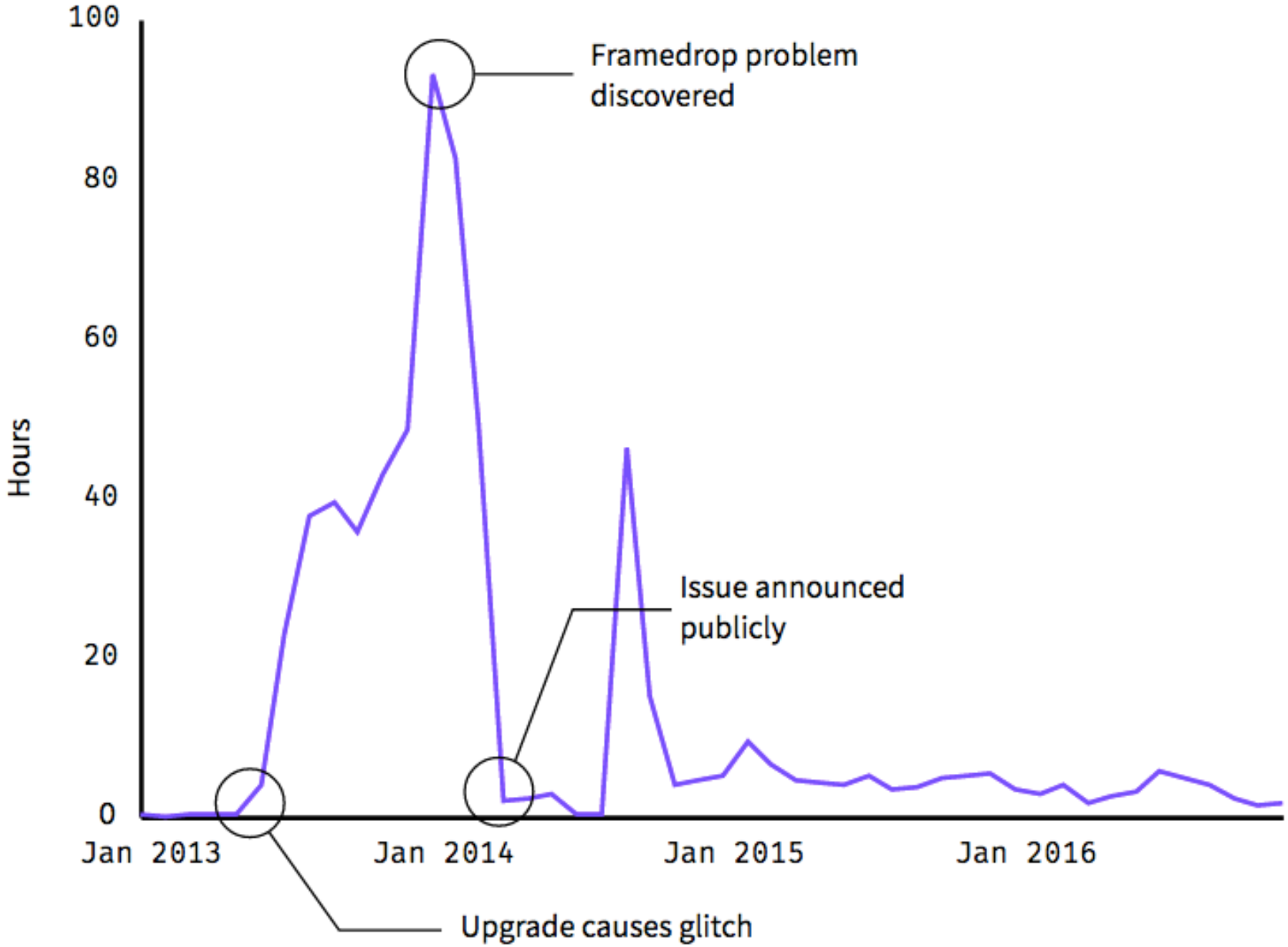


Taxonomy of Interactions

Data and View Specification
Visualize, Filter, Sort, Derive

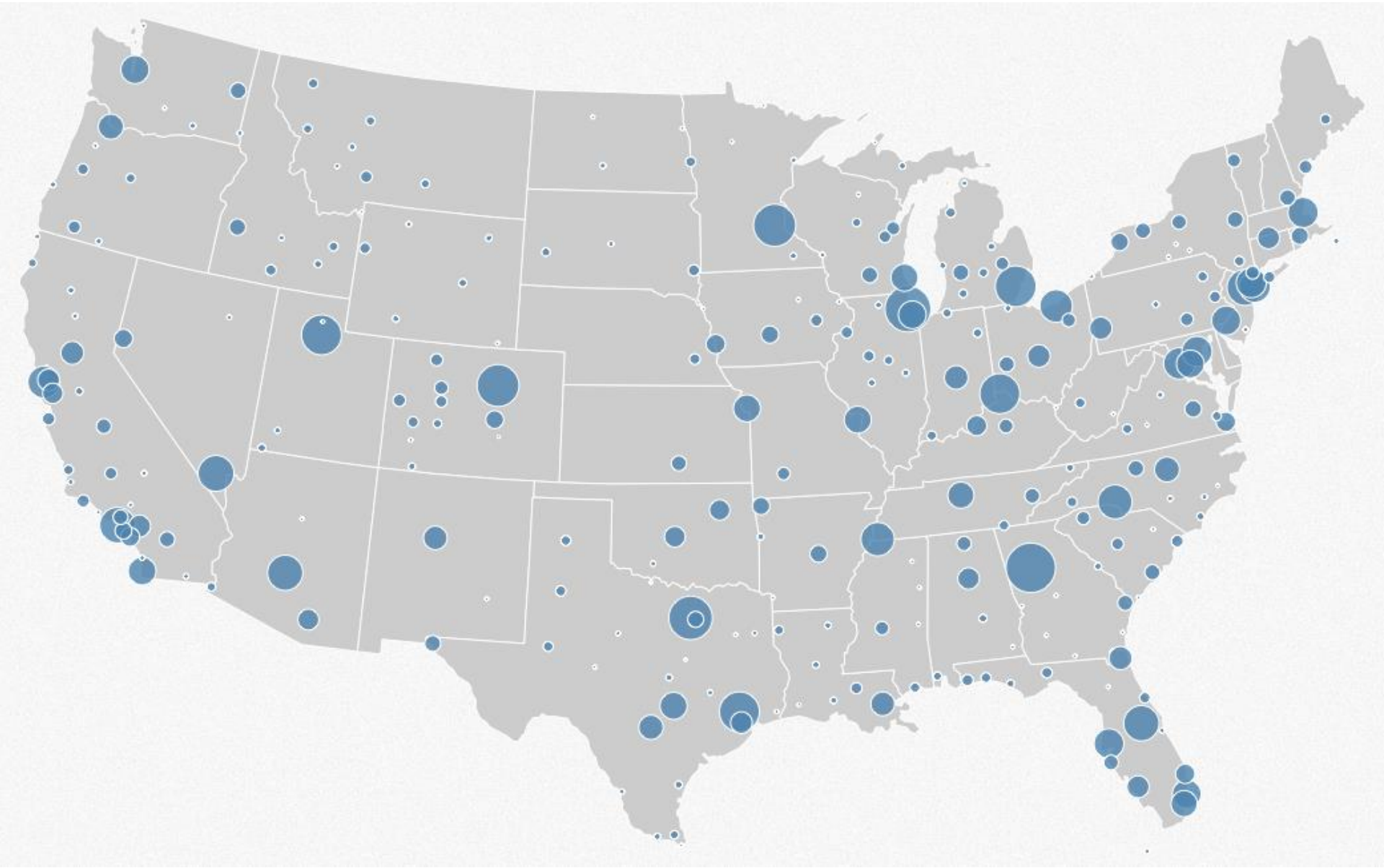
View Manipulation
Select, Navigate, Coordinate, Organize

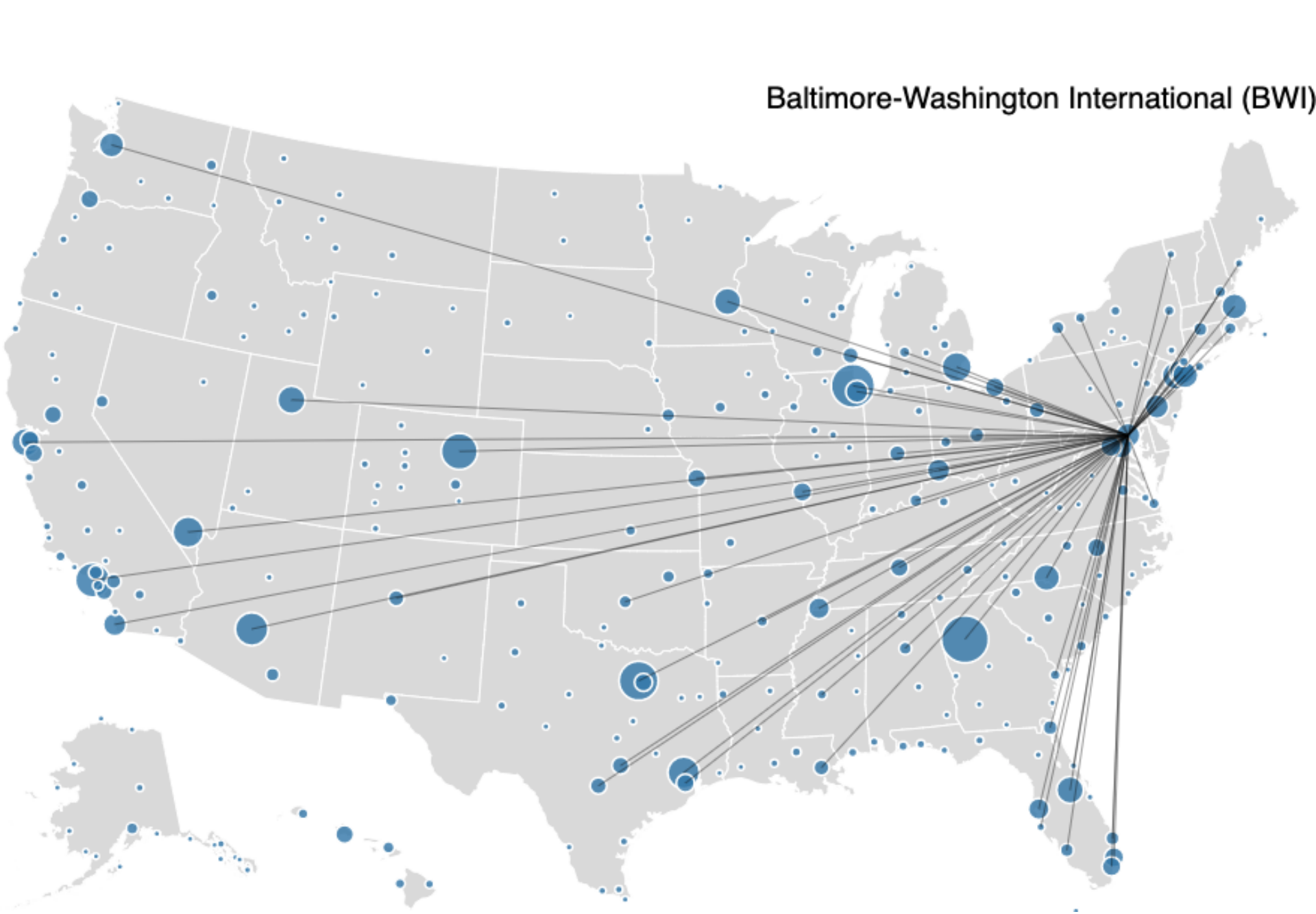
Process and Provenance
Record, Annotate, Share, Guide

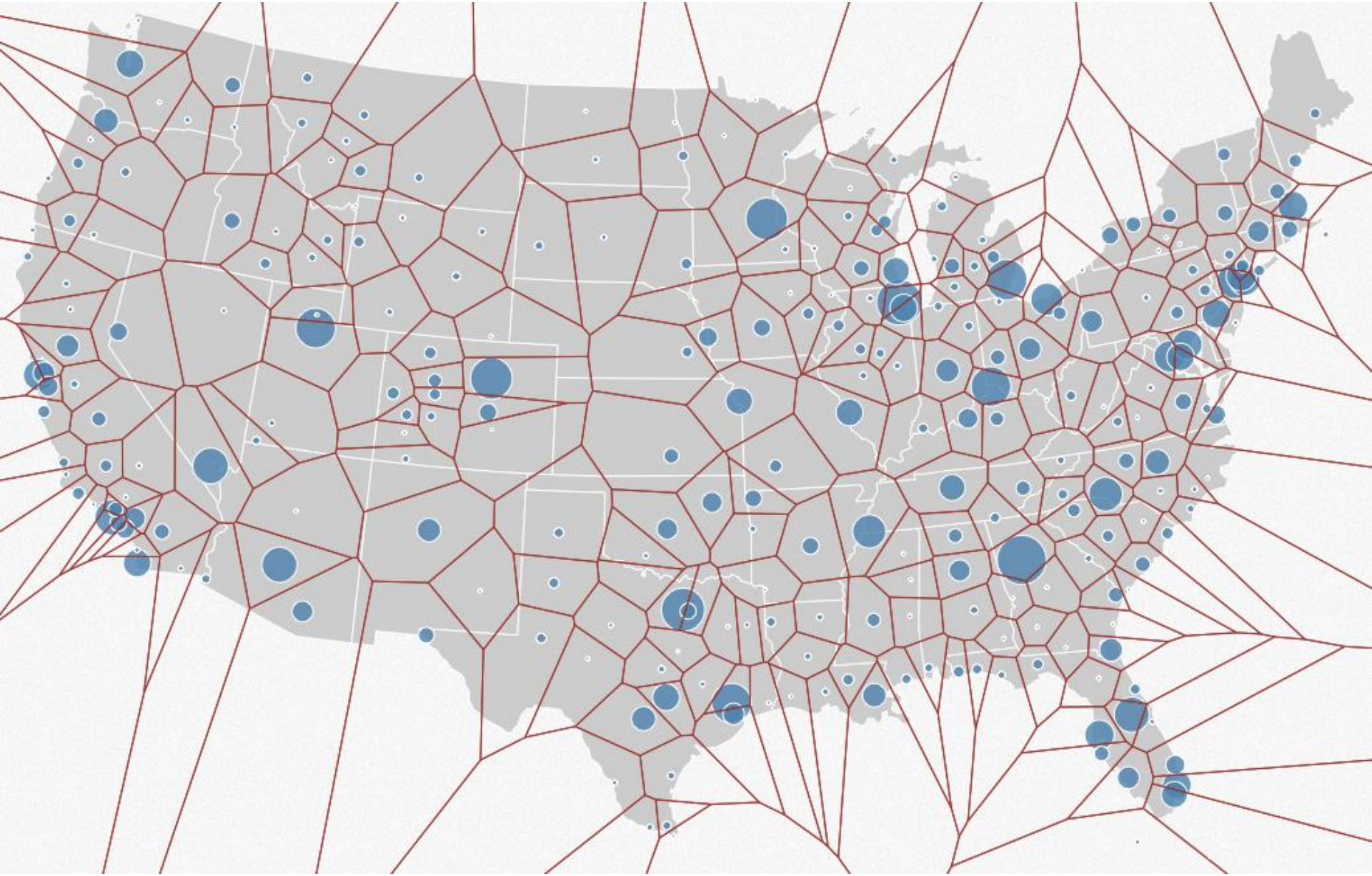
Selection

Basic Selection Methods

Point Selection
Mouse Hover / Click
Touch / Tap
Select Nearby Element (e.g., Bubble Cursor)




Baltimore-Washington International (BWI)



Basic Selection Methods

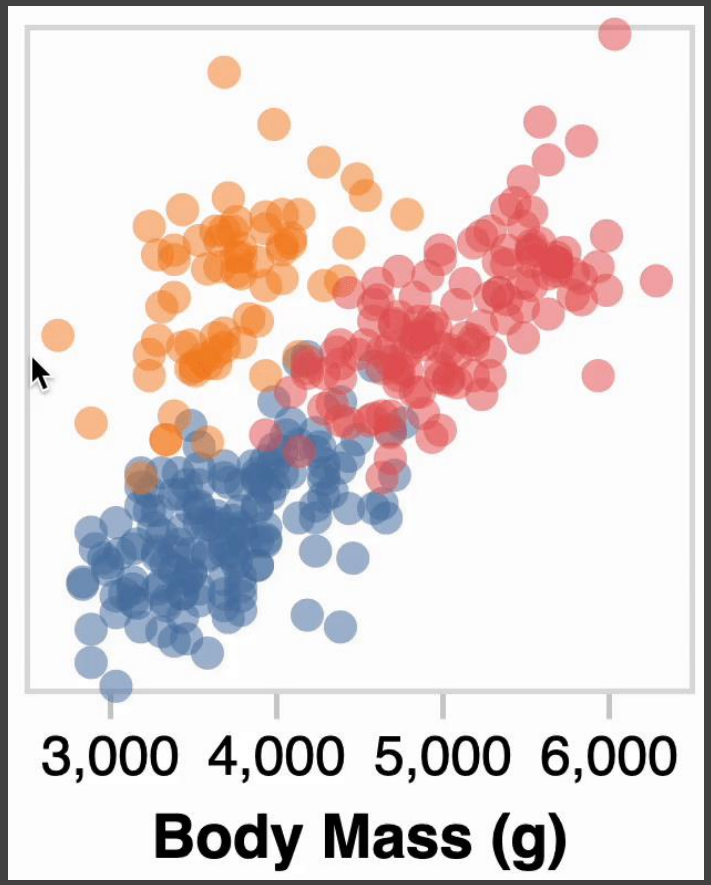
Point Selection
Mouse Hover / Click
Touch / Tap
Select Nearby Element (e.g., Bubble Cursor)

Region Selection
Rubber-band (rectangular) or Lasso (freehand)
Area cursors (“brushes”)

Brushing & Linking

Brushing

Direct attention to a subset of data

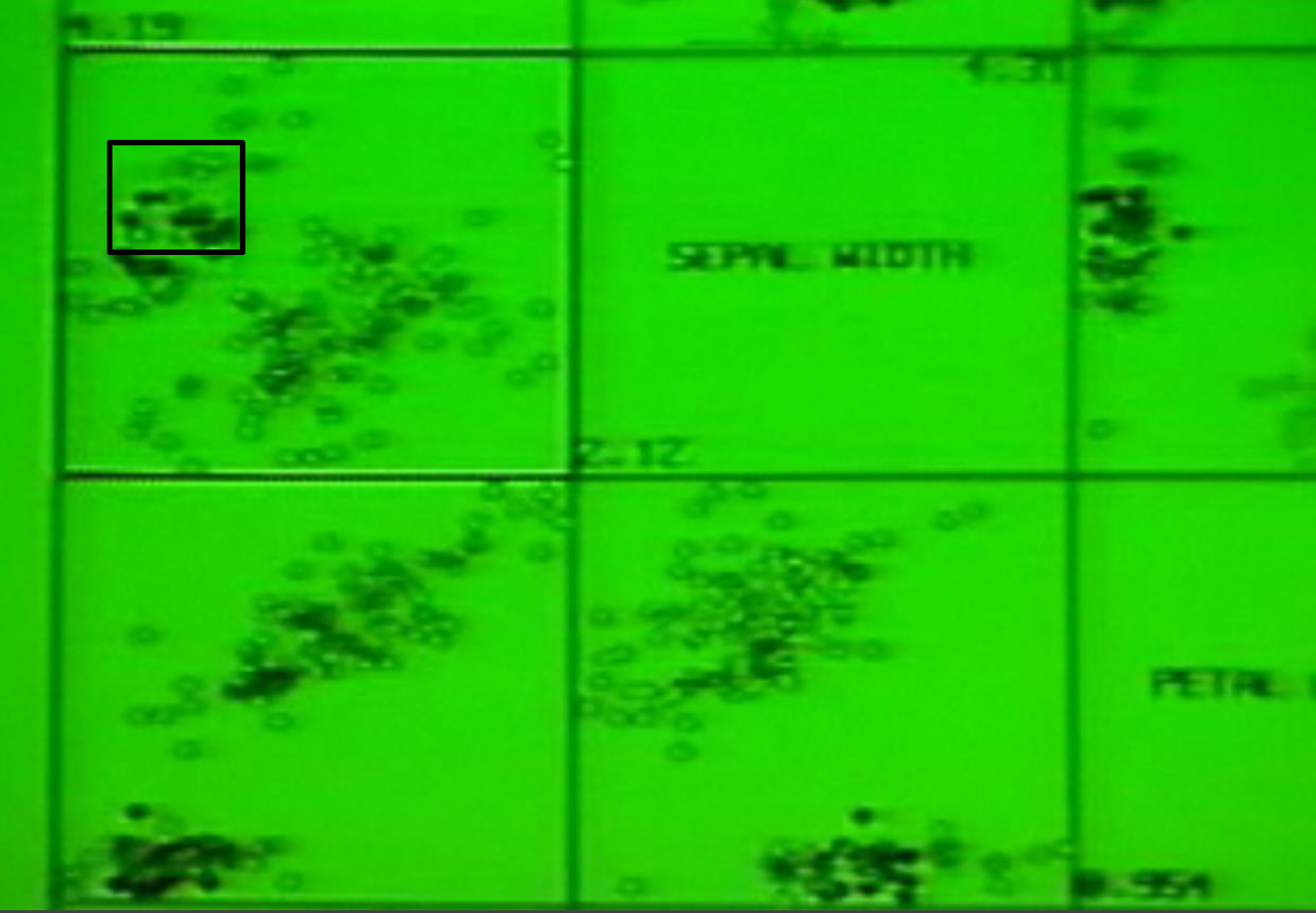


https://vega.github.io/vega/examples/brushing-scatter-plots/

Brushing & Linking

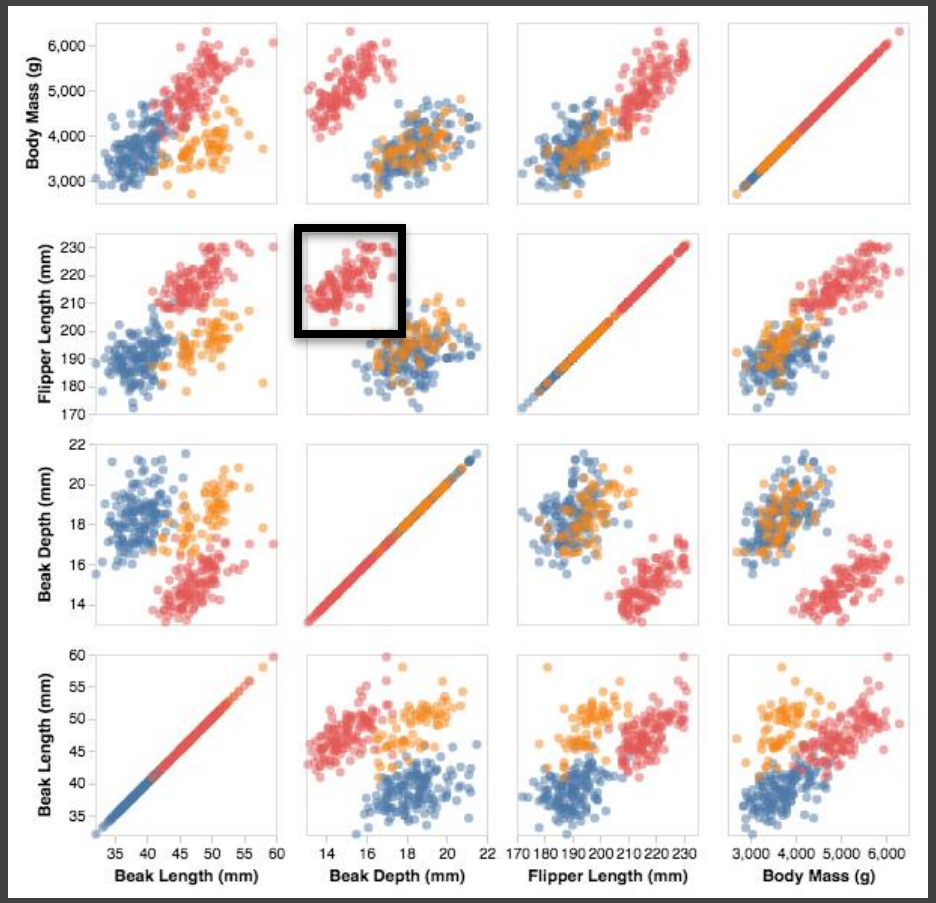
Select ("***brush***") a subset of data
See selected data in other views

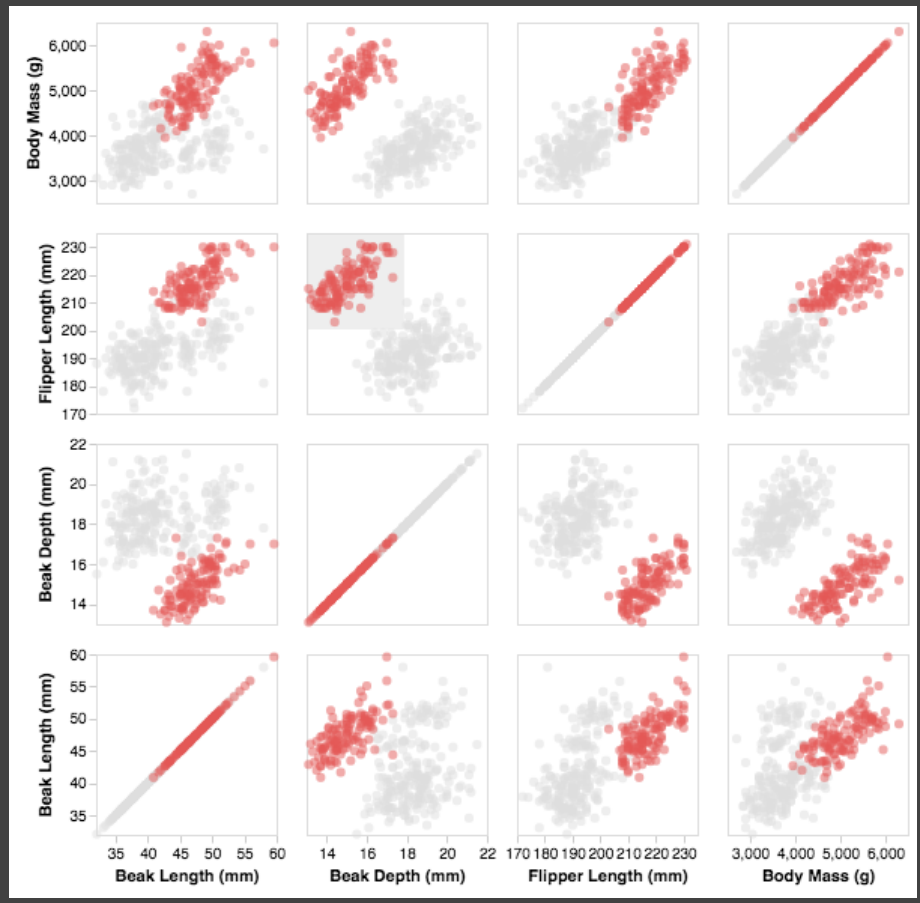
The components must be ***linked***
by *tuple* (matching data points), or
by *query* (matching range or values)



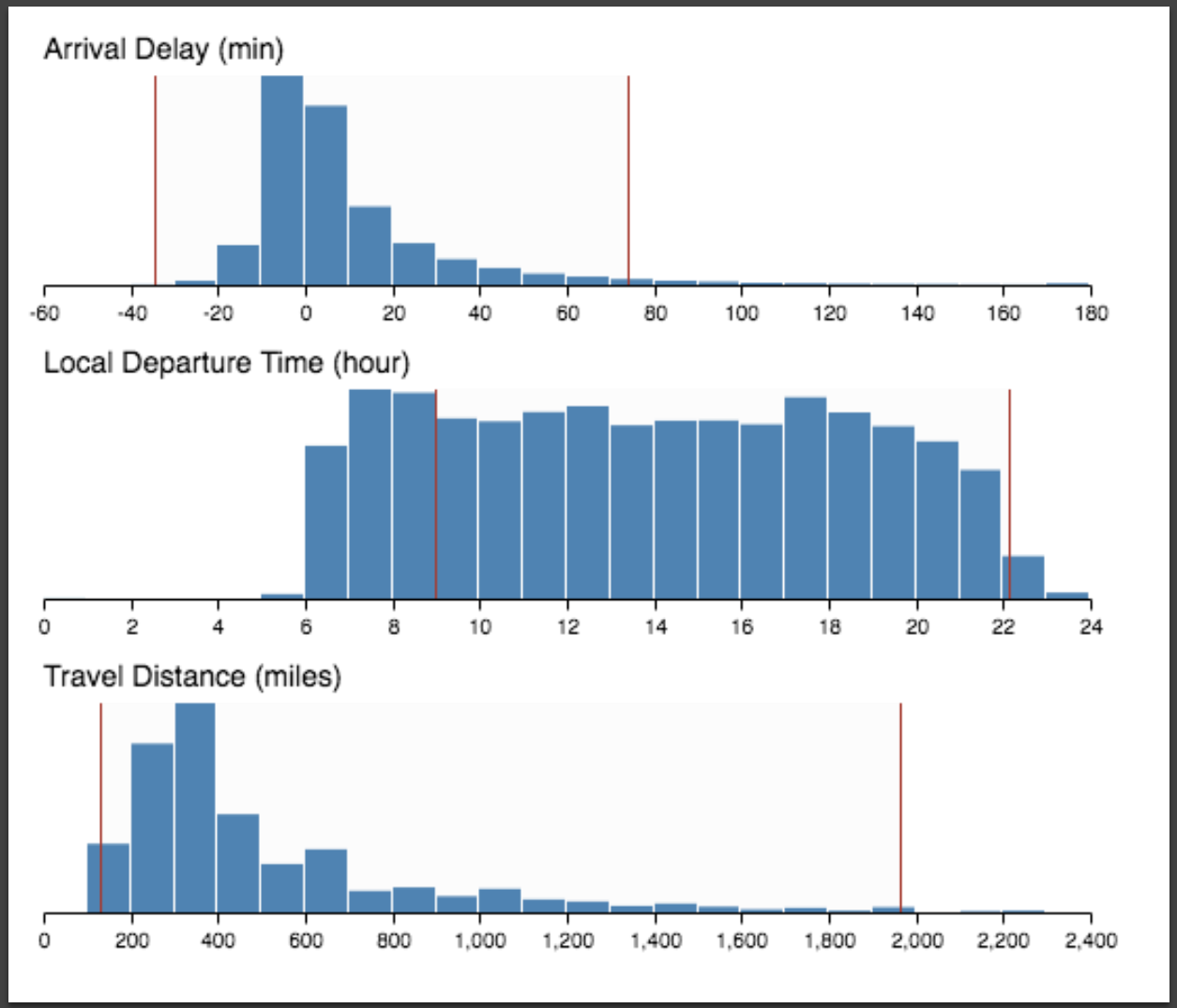
Brushing Scatterplots, Becker & Cleveland 1982

Brushing Scatterplots

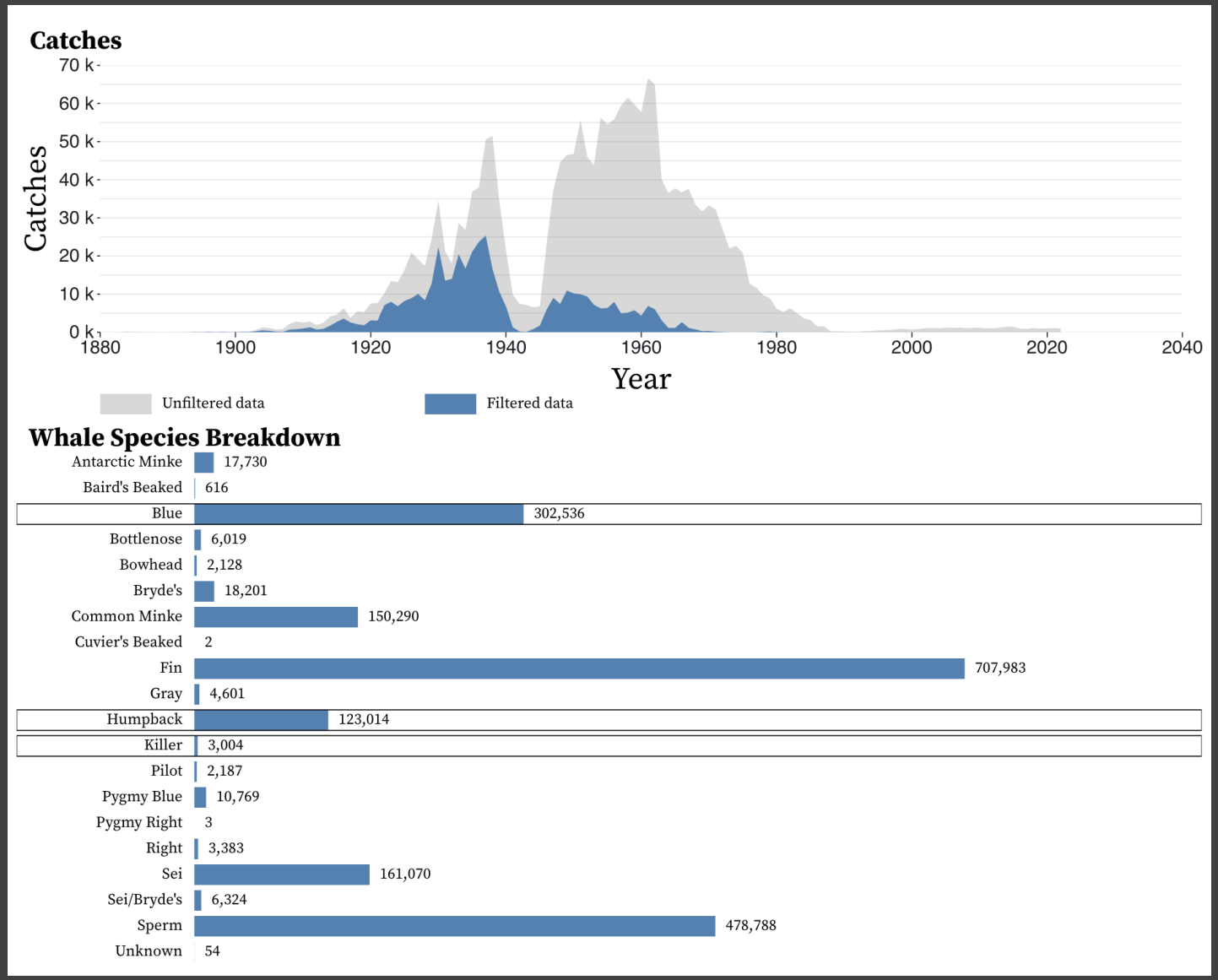




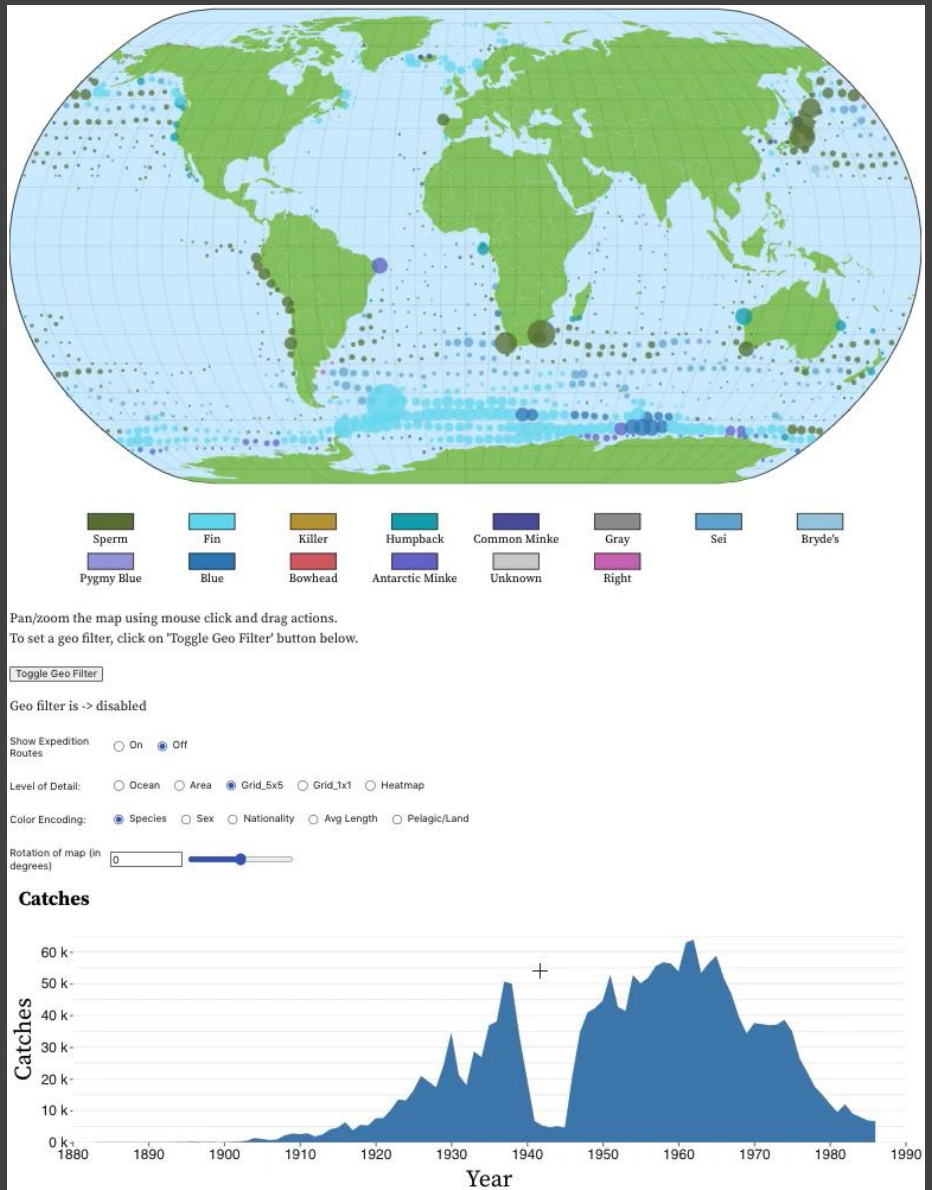
Cross-Filtering



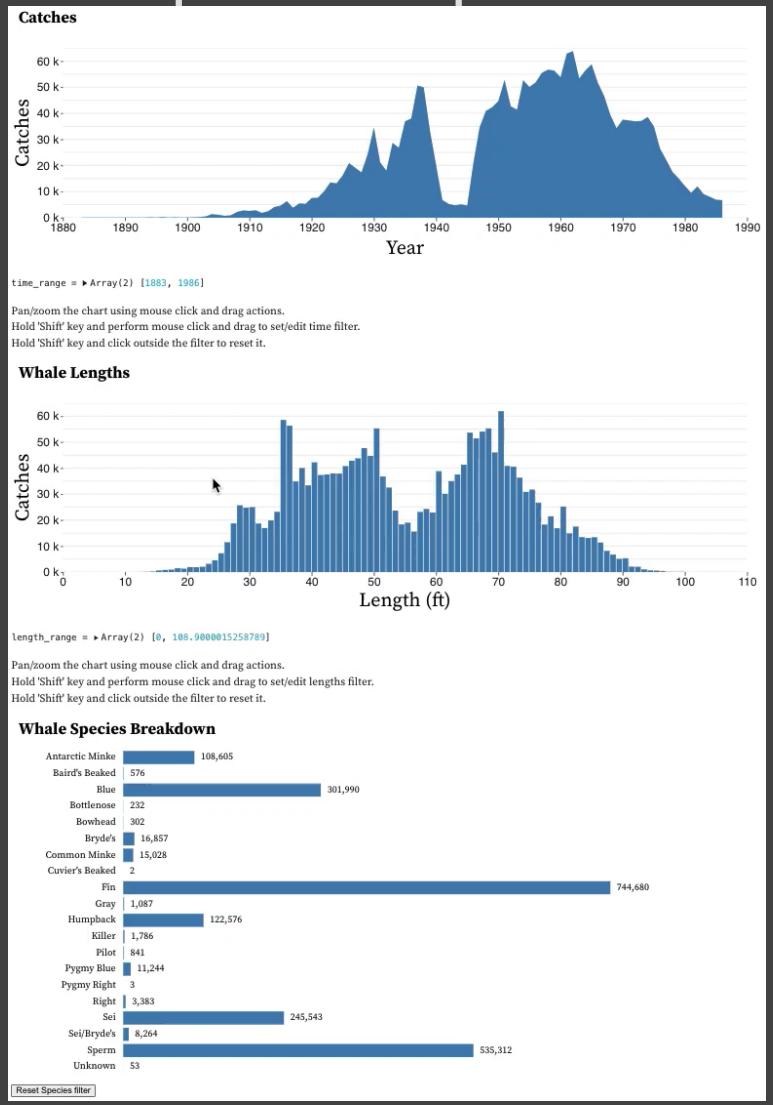
Analyzing Whale Catches [Patil 23]



Linking Time and Location [Patil 23]



Linking Catches with Whale Characteristics [Patil 23]



Break Time!

Administrivia

A2: Deceptive Visualization

Design **two** static visualizations for a dataset:
1. An *earnest* visualization that faithfully conveys the data
2. A *deceptive* visualization that tries to mislead viewers

Your two visualizations may address different questions.

Try to design a deceptive visualization that appears to be earnest: *can you trick your classmates and course staff?*

You are free to choose your own dataset, but we have also provided some preselected datasets for you.

Submit two images and a brief write-up on Gradescope.

Due by **Wed 1/29 11:59pm**.

A2 Peer Reviews

On Thursday 10/20 you will be assigned two peer A2 submissions to review. For each:

- Try to determine which is earnest and which is deceptive
- Share a rationale for how you made this determination
- Share feedback using the “I Like / I Wish / What If” rubric

Assigned reviews will be posted on the A2 Peer Review page on Canvas, along with a link to a Google Form. You should submit two forms: one for each A2 peer review.

Due by **Tues 2/4 11:59pm**.

I Like… / I Wish… / What If?

I LIKE…
Praise for design ideas and/or well-executed implementation details. *Example: "I like the navigation through time via the slider; the patterns observed as one moves forward are compelling!”*

I WISH…
Constructive statements on how the design might be improved or further refined. *Example: "I wish moving the slider caused the visualization to update immediately, rather than the current lag."*

WHAT IF?
Suggest alternative design directions, or even wacky half-baked ideas. *Example: "What if we got rid of the slider and enabled direct manipulation navigation by dragging data points directly?"*

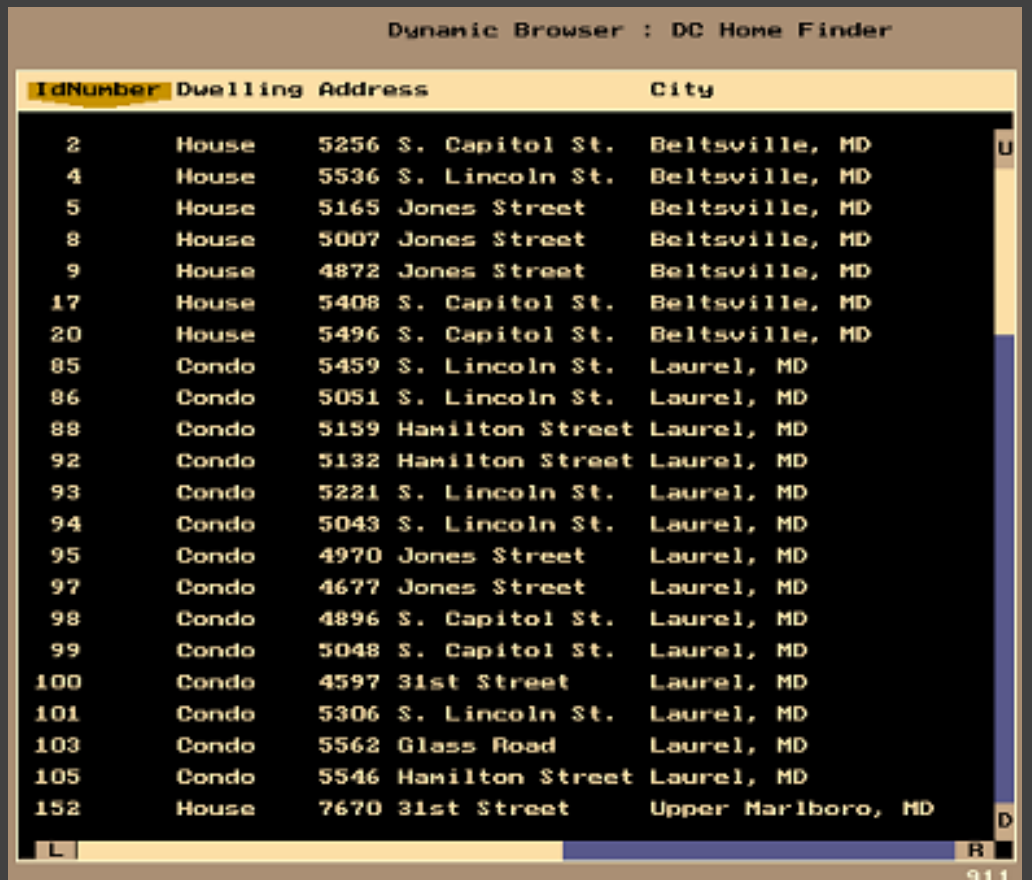
Dynamic Queries

Query & Results

SELECT house FROM seattle_homes

WHERE price < 1,000,000 AND bedrooms > 2

ORDER BY price



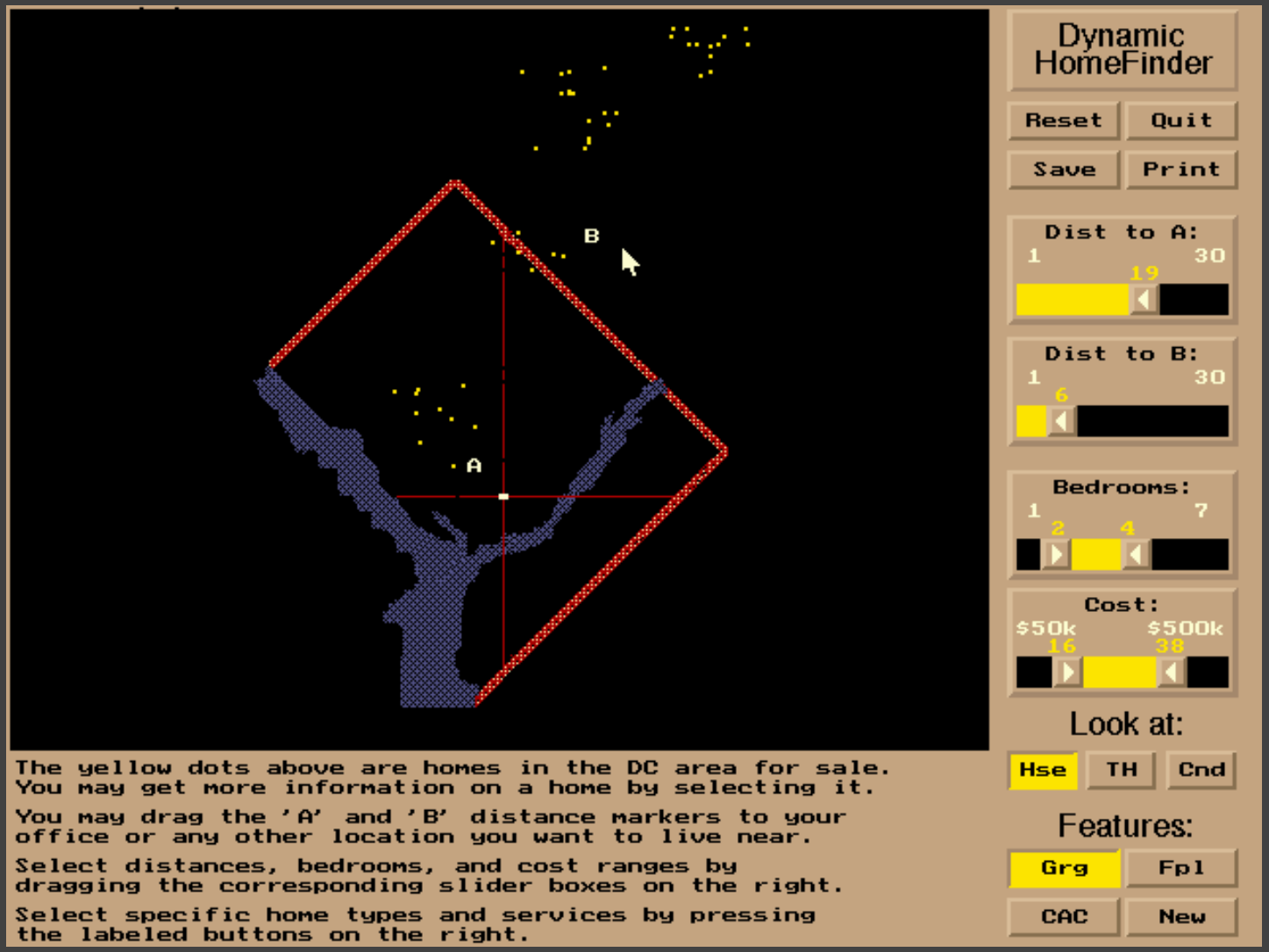
What are Some Drawbacks to Textual Queries?

What are some potential downsides to assuming a text-based query interface for data analysis?

Issues with Textual Queries

1. For programmers
2. Rigid syntax
3. Only shows exact matches
4. Too few or too many hits
5. No hint on how to reformulate the query
6. Slow question-answer loop
7. Results returned as table

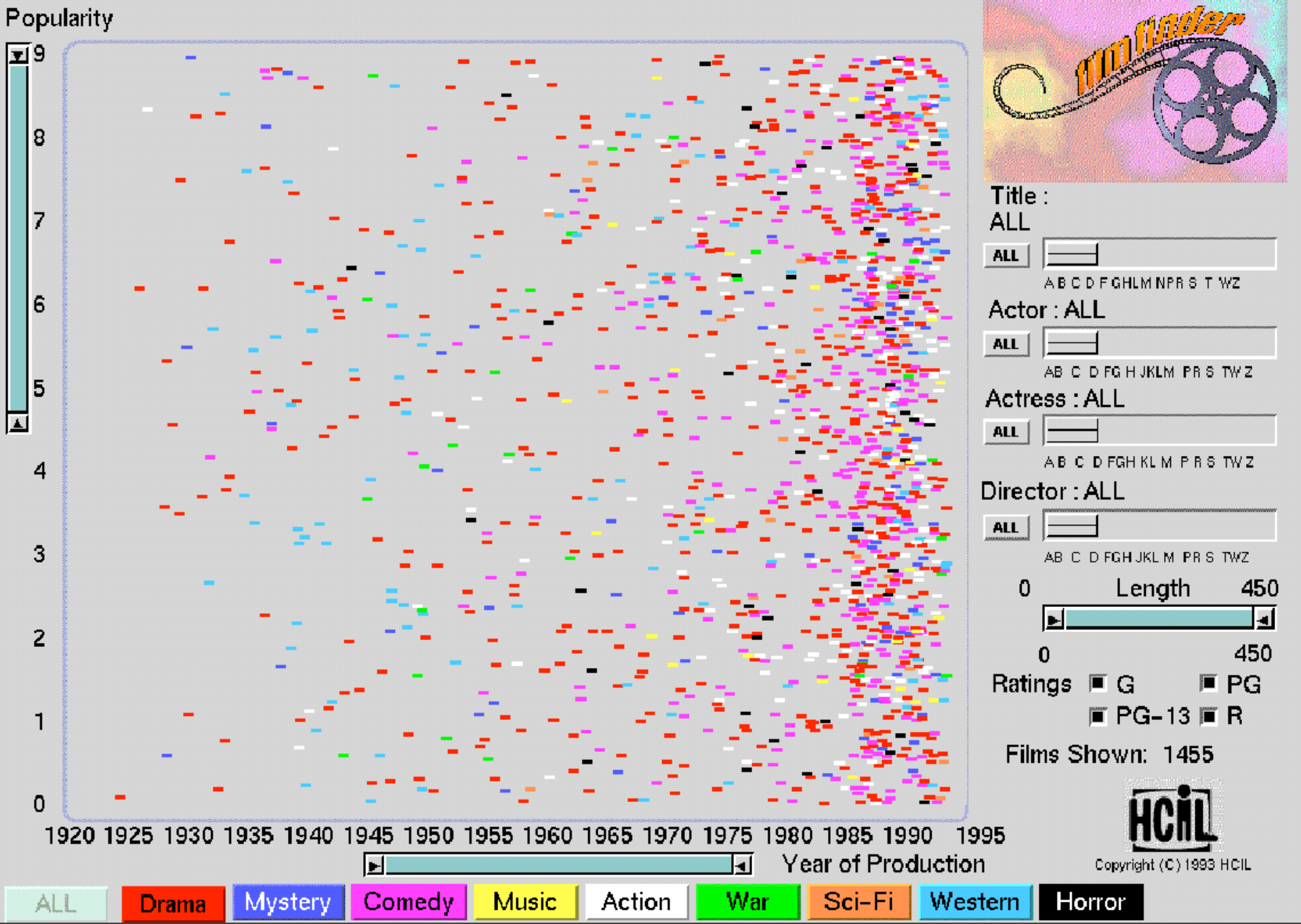
HomeFinder



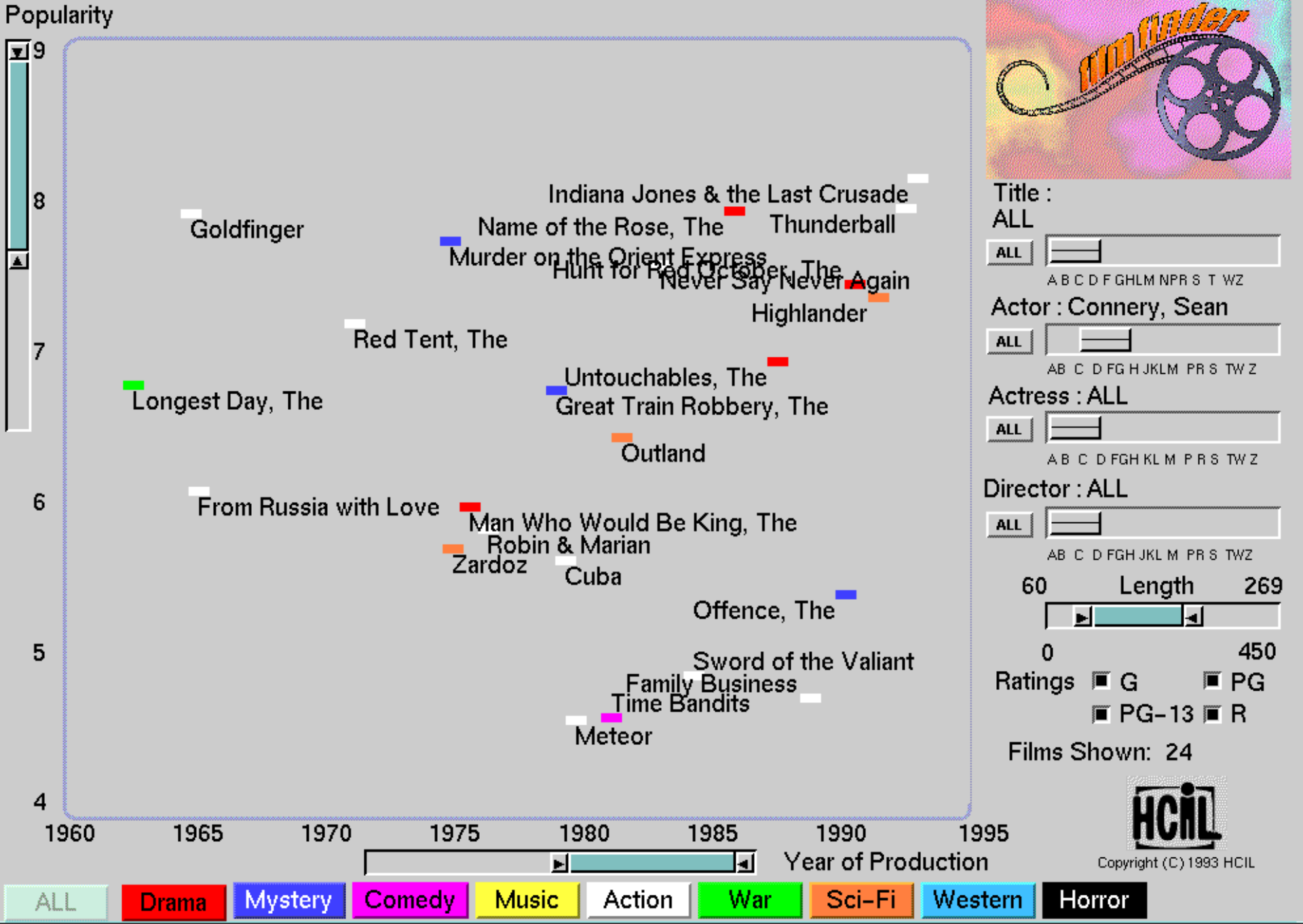
[Williamson and Shneiderman 92]

Direct Manipulation

1. Visual representation of objects and actions
2. Rapid, incremental and reversible actions
3. Selection by pointing (not typing)
4. Immediate and continuous display of results



[Ahlberg and Shneiderman 94]

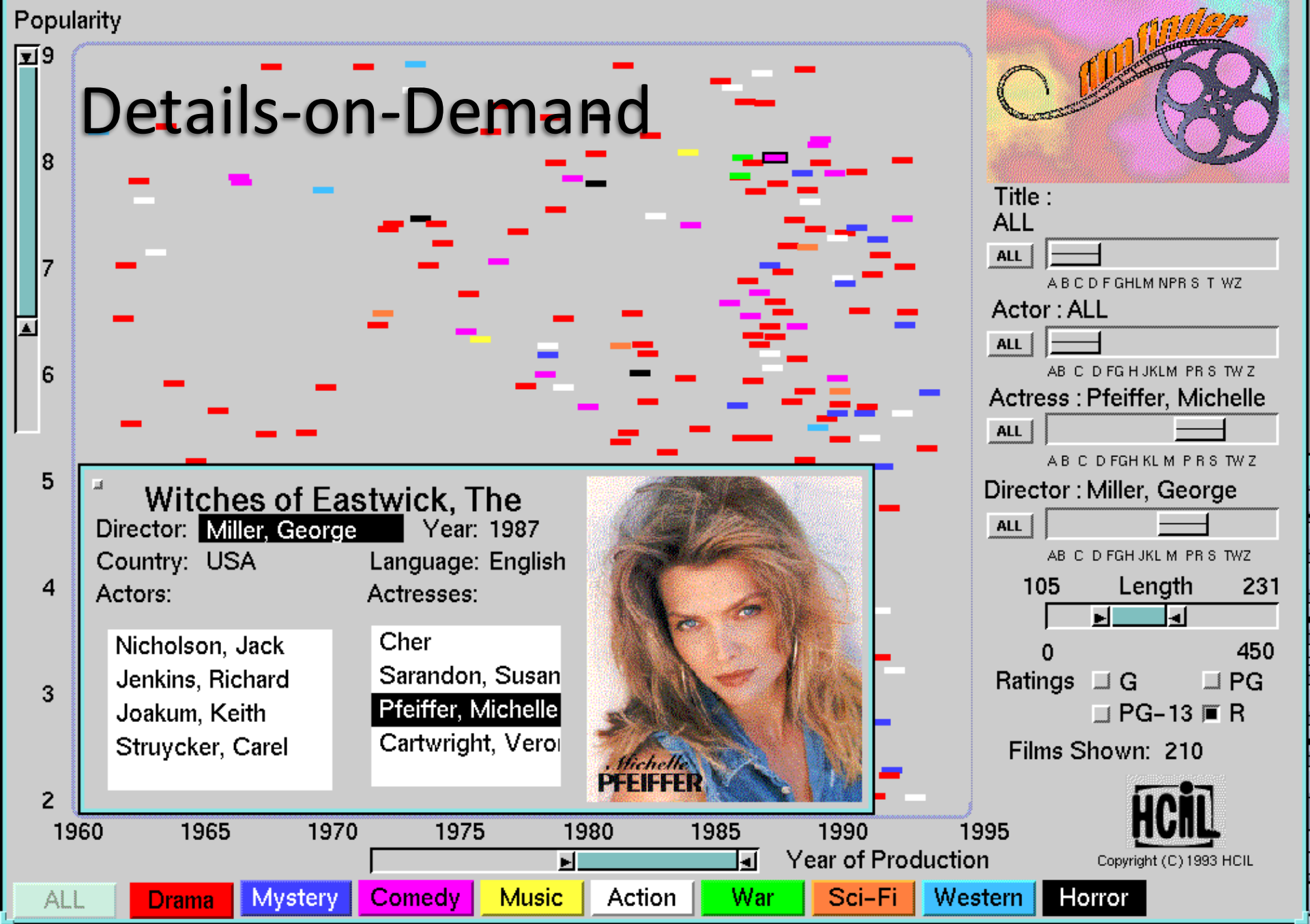


[Ahlberg and Shneiderman 94]

Alphaslider (?)

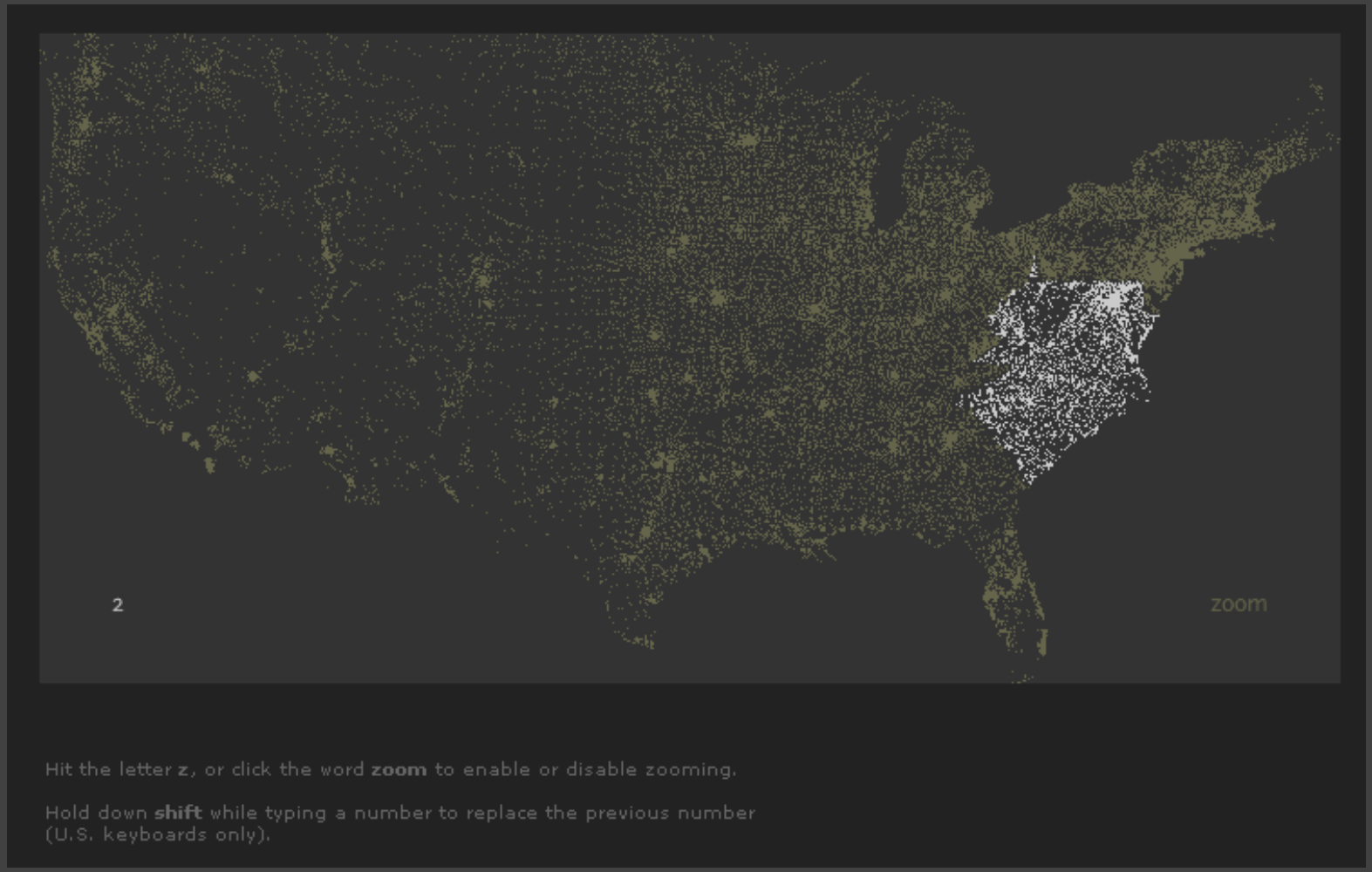
[Ahlberg and Shneiderman 94]

Details-on-Demand



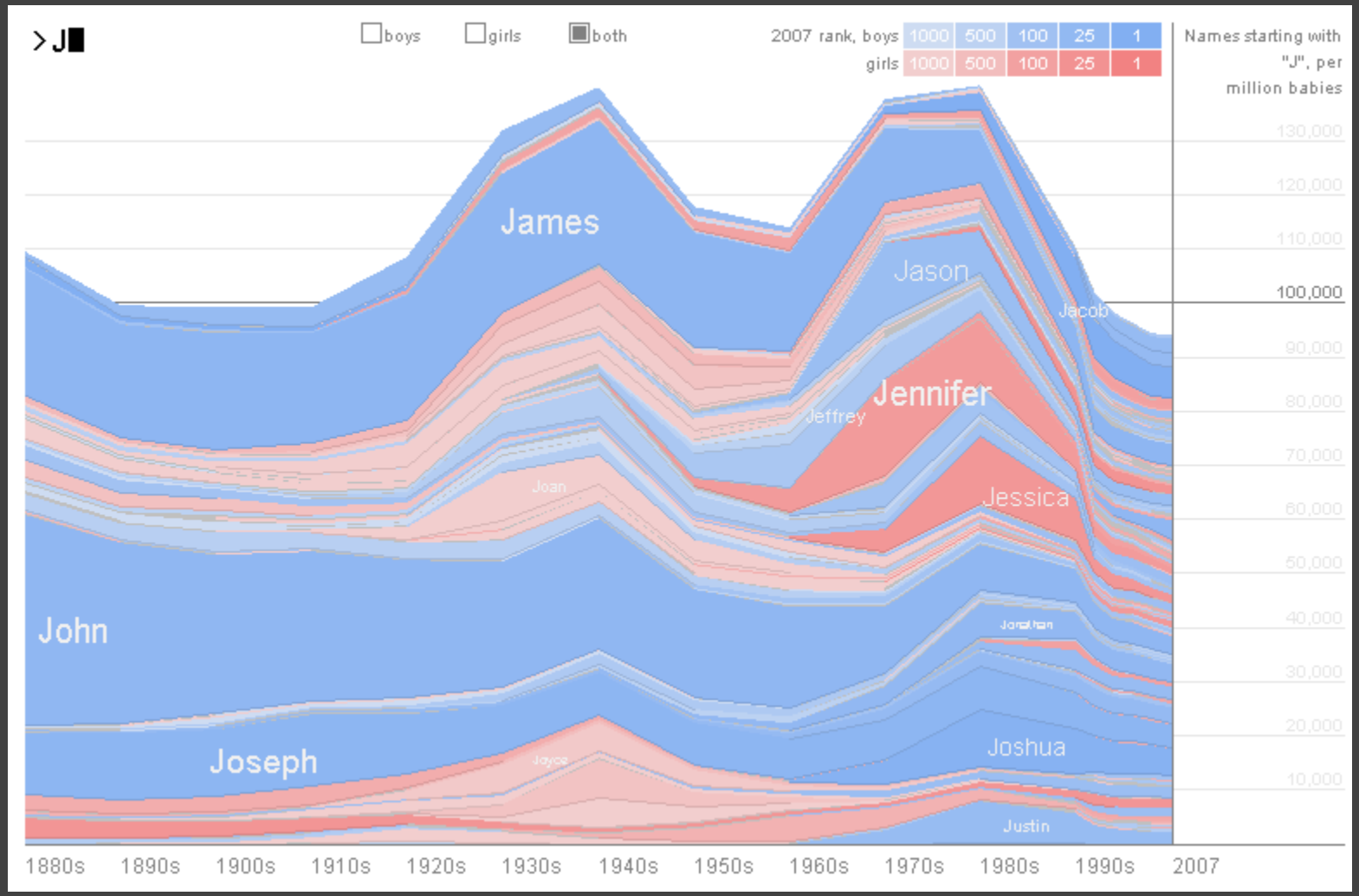
[Ahlberg and Shneiderman 94]

Zipdecode [Fry 04]



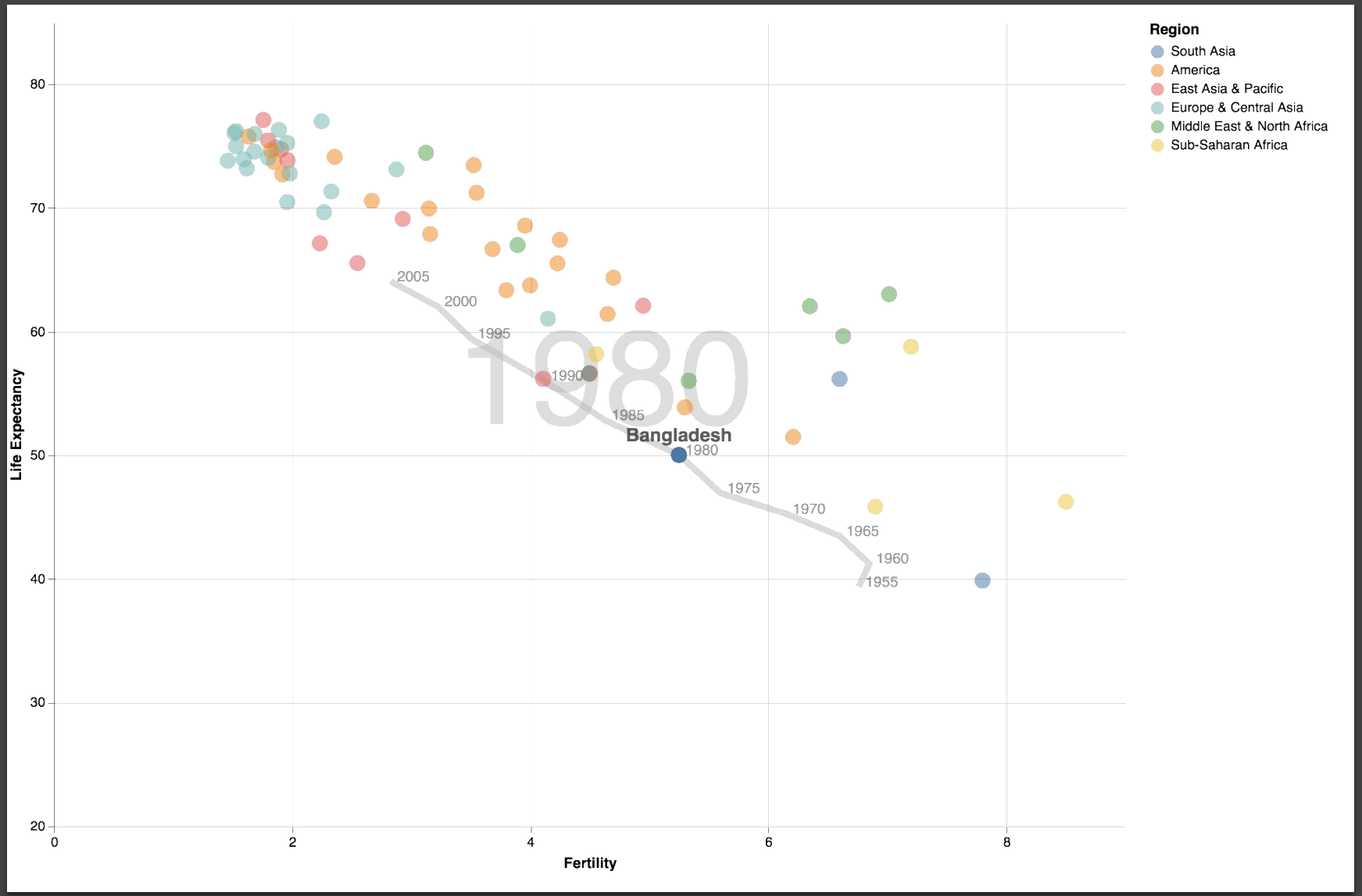
http://benfry.com/zipdecode/

NameVoyager [Wattenberg 06]

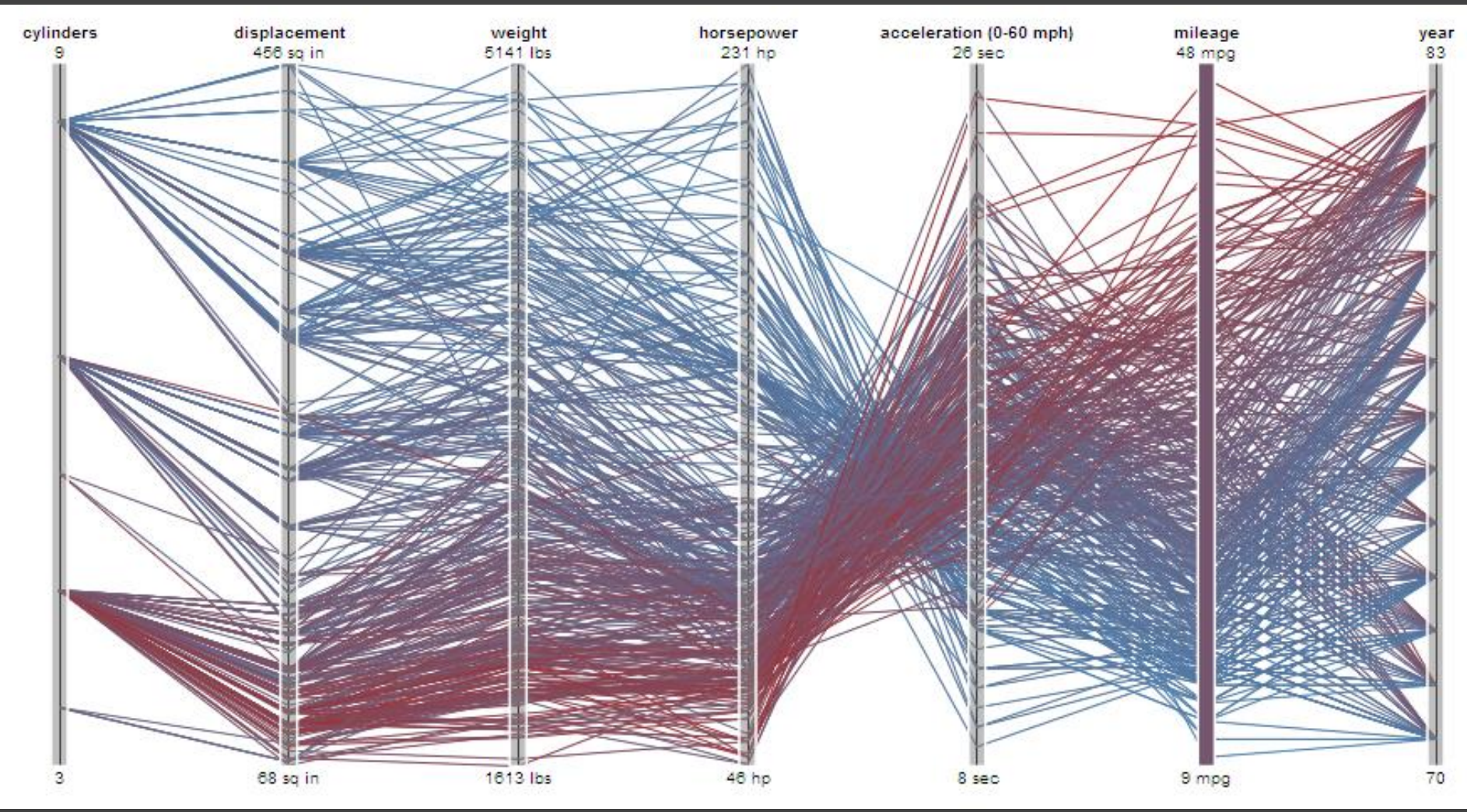


http://www.babynamewizard.com/voyager

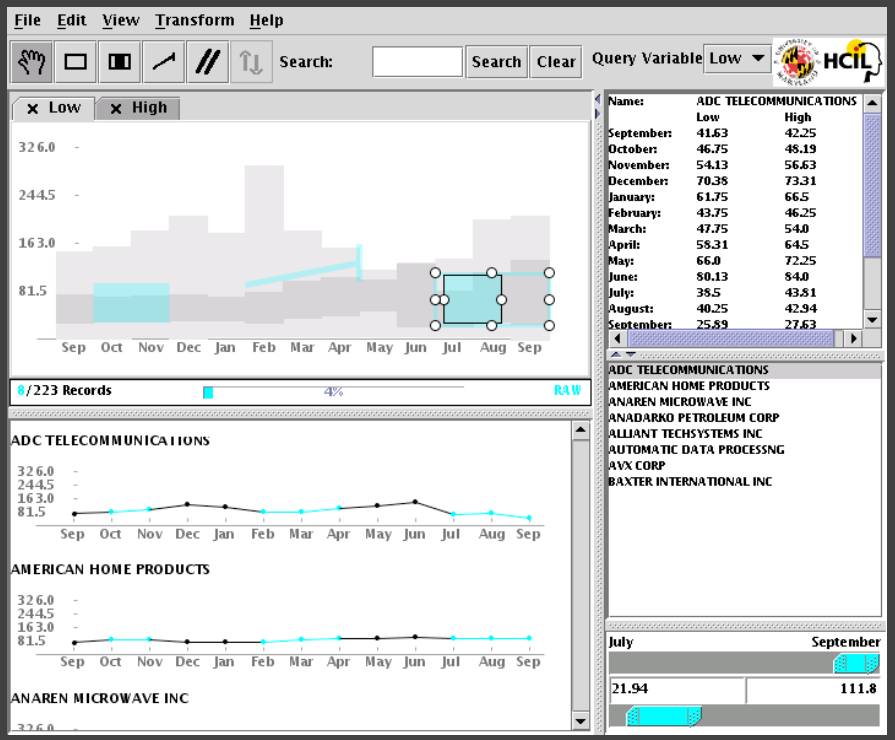
DimpVis [Kondo 14]

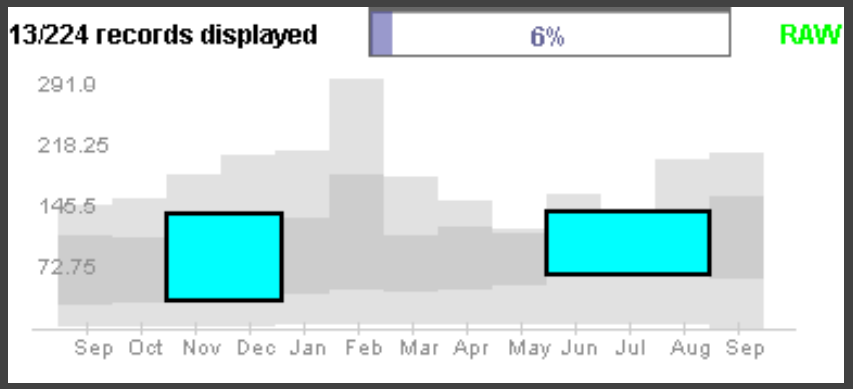


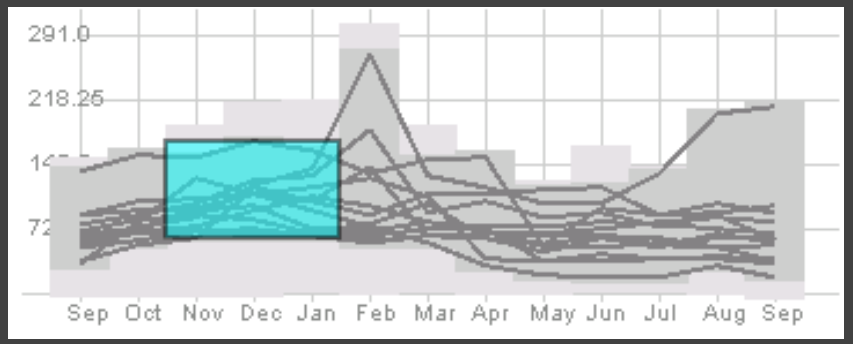
Parallel Coordinates [Inselberg]



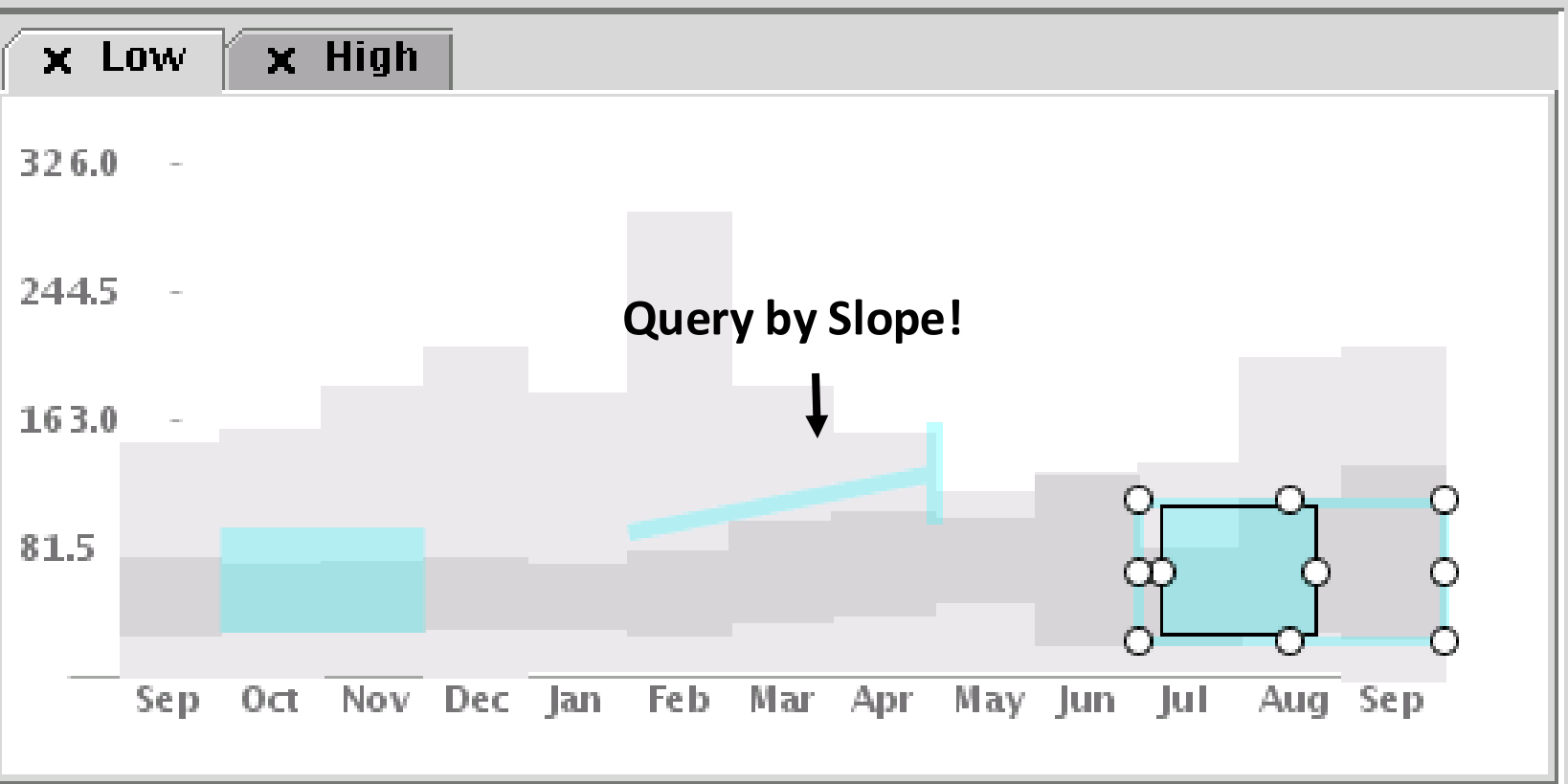
TimeSearcher [Hocheiser 02]

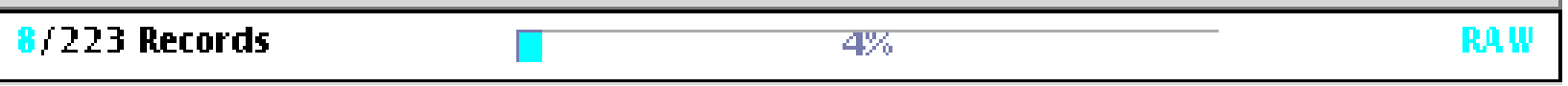


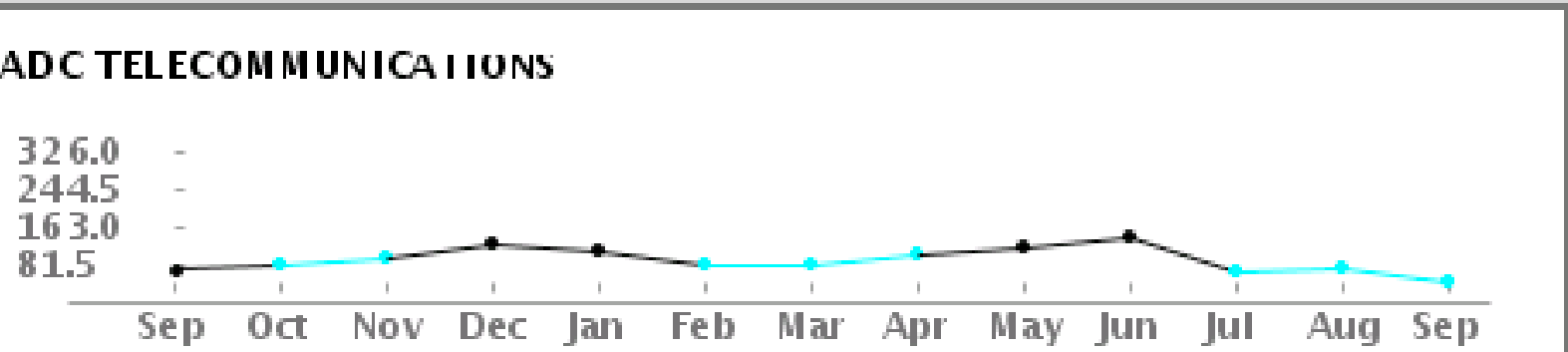




Builds on Wattenberg's [2001] idea for sketch-based queries of time-series data.

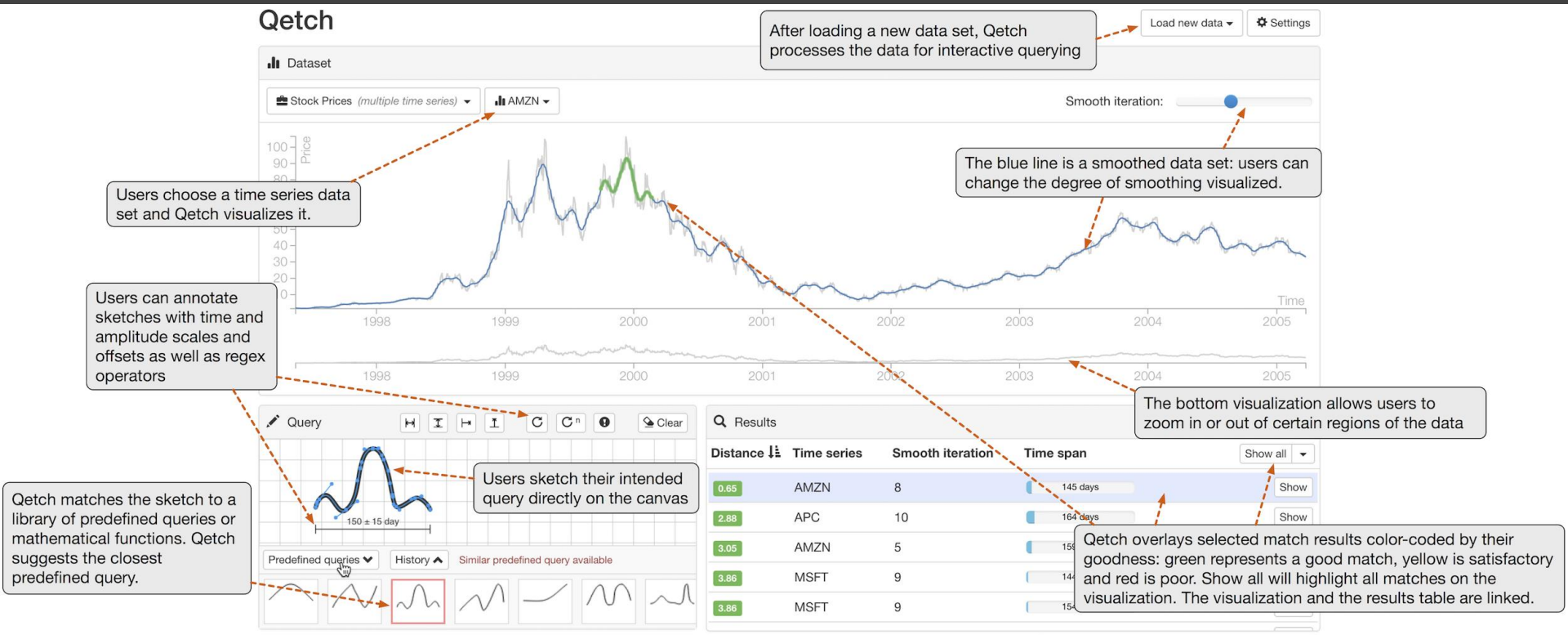






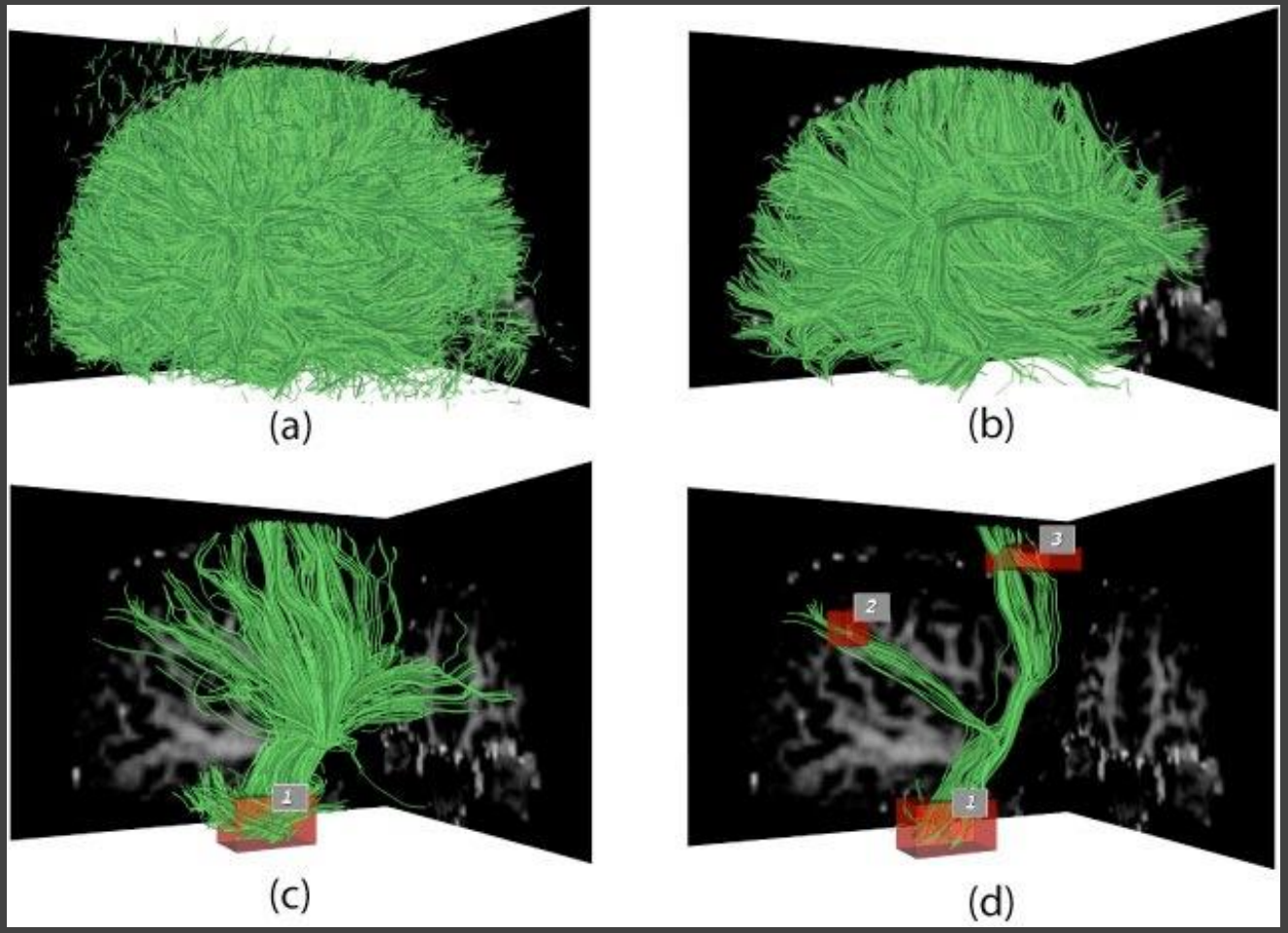
AMERICAN HOME PRODUCTS

Qetch [Mannino 18]

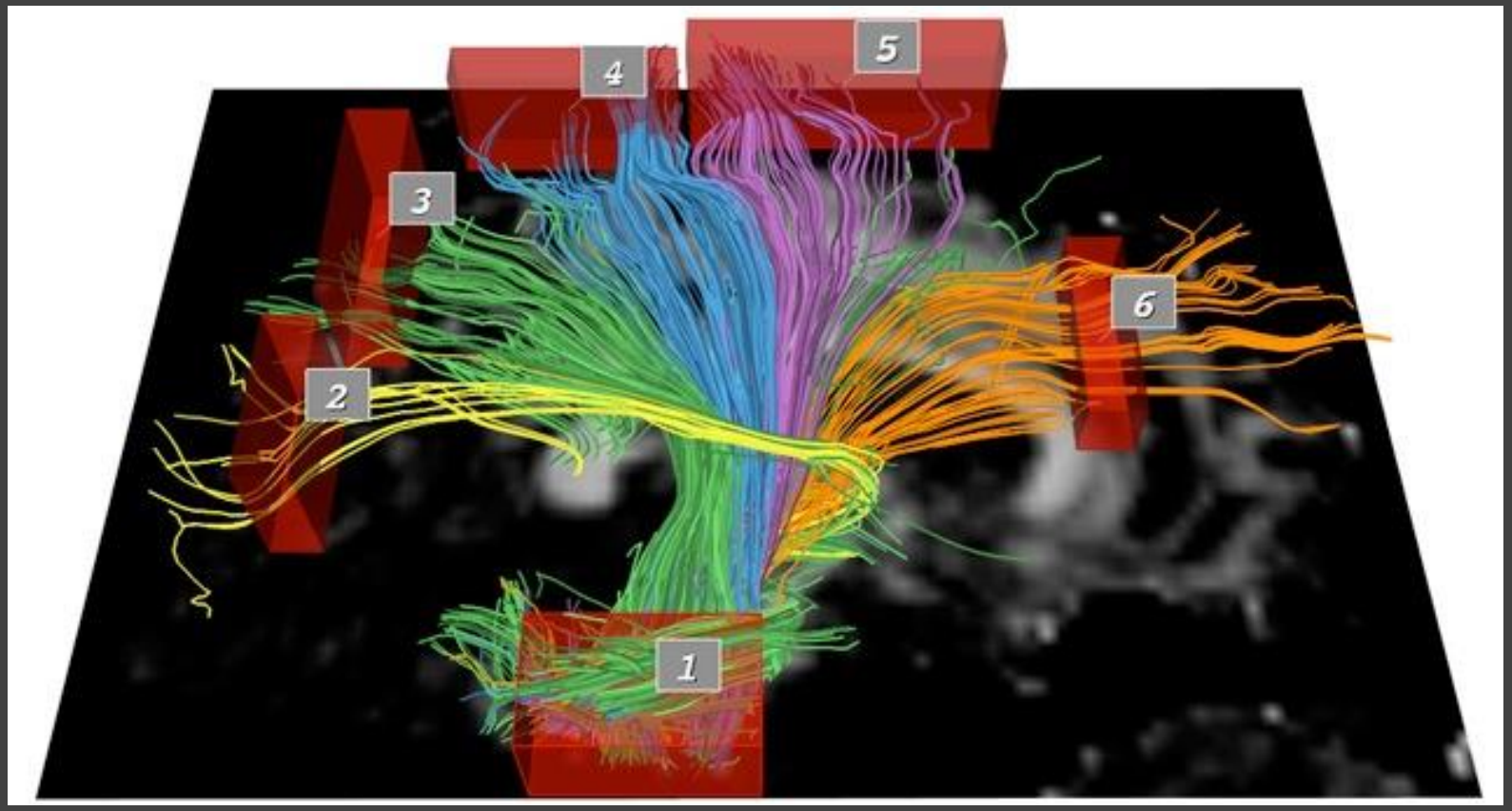


Supports freehand sketching of temporal patterns to interactively query time series.

3D Dynamic Queries [Akers 04]



3D Dynamic Queries [Akers 04]



Pros & Cons

Pros
Controls useful for both novices and experts
Quick way to explore data

Pros & Cons

Pros
Controls useful for both novices and experts
Quick way to explore data

Cons
Simple queries
Lots of controls
Amount of data shown limited by screen space

Who would use these kinds of tools?

Summary

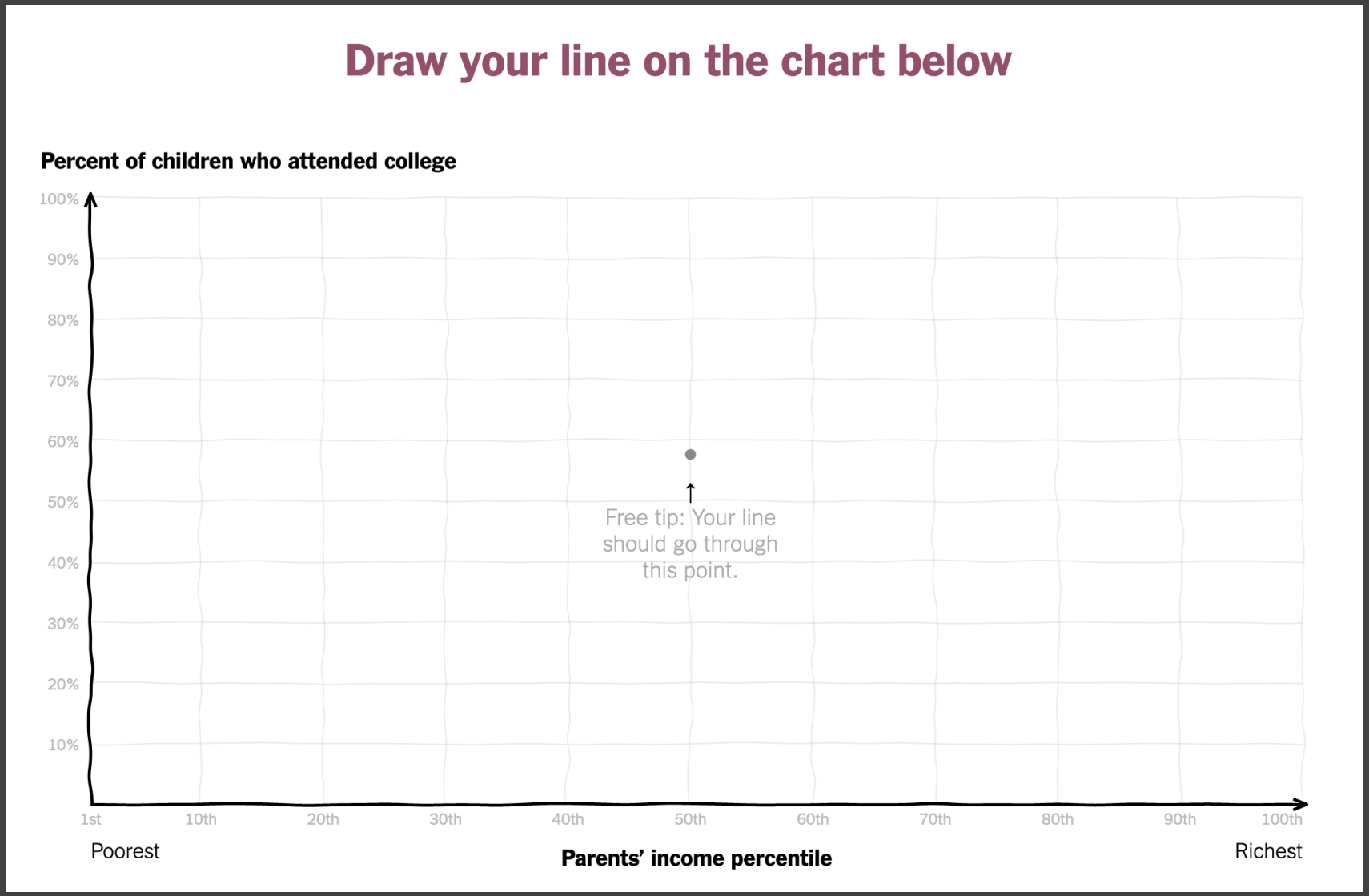
Most visualizations are interactive

Even passive media elicit interactions
Good visualizations are task dependent
Pick the right interaction technique

Consider the semantics of the data domain
Fundamental interaction techniques
Selection / Annotation, Sorting, Navigation,
Brushing & Linking, Dynamic Queries

Prompting Reflection

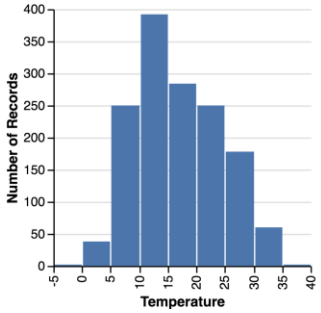
You Draw It [Aisch et al. '15]



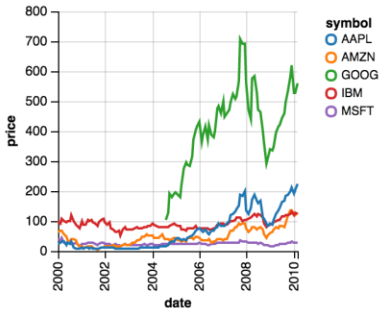
An Interaction Grammar (Vega-Lite Selections)

Satyanarayan, Moritz, Wongsuphasawat, Heer. *TVCG'17*

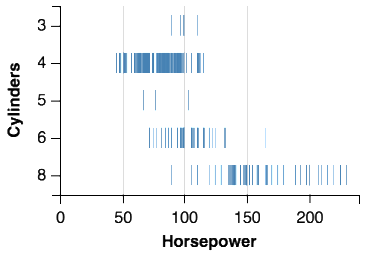
Histogram



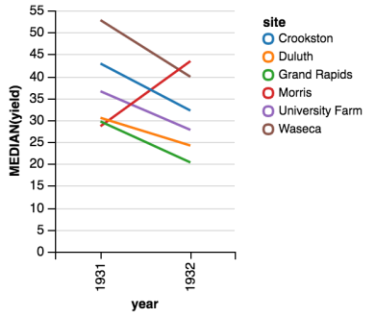
Line Chart



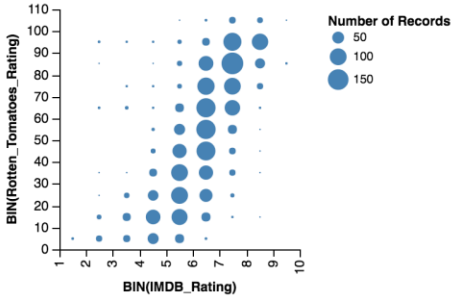
Strip Plot



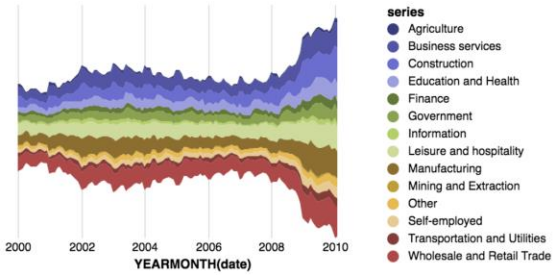
Slope Graph



Binned Scatter Plot

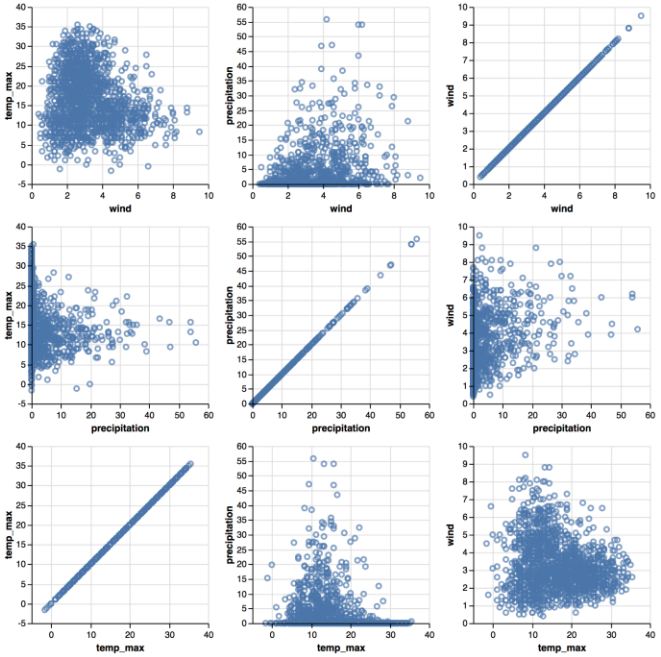


Area Chart

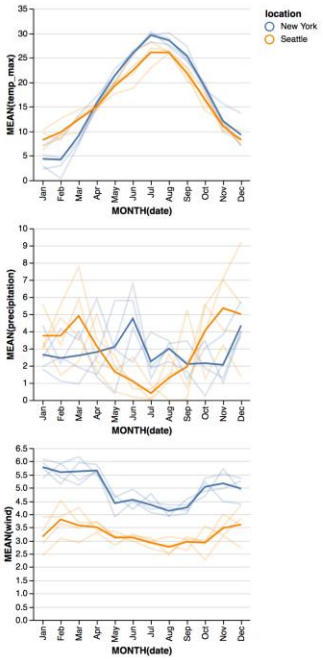


Vega-Lite: A Grammar of Graphics

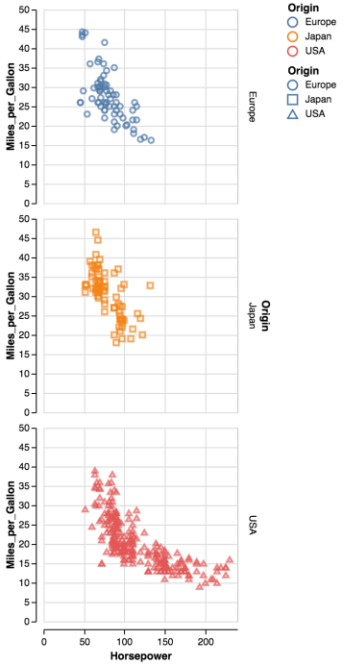
Scatter Plot Matrix



Concat & Layered Views

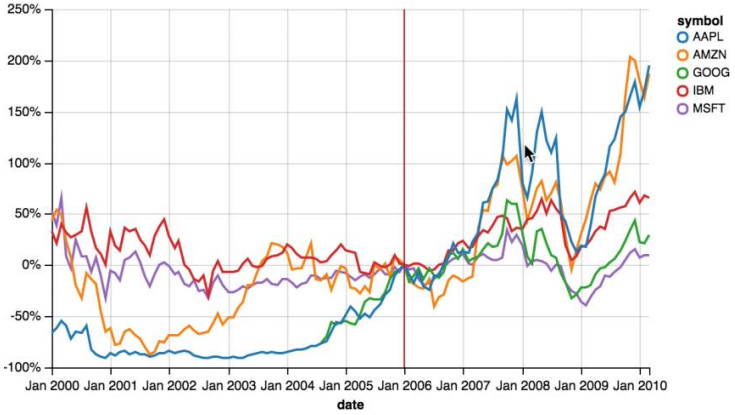


Faceted Views

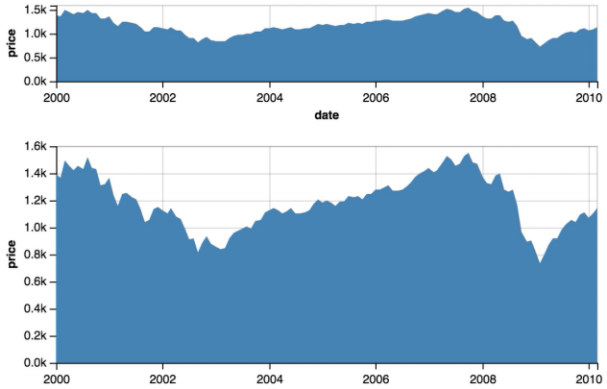


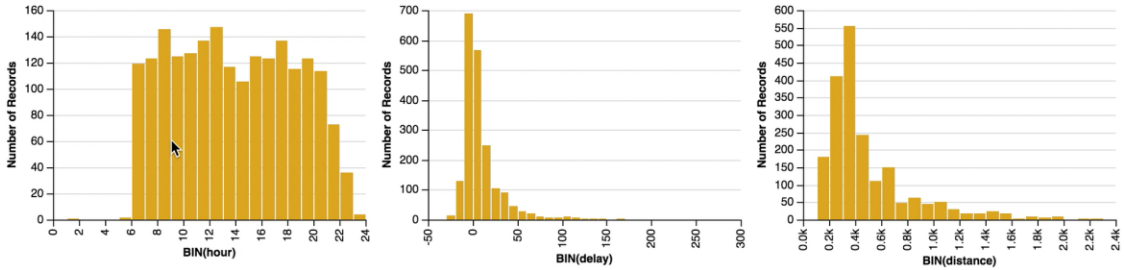
Vega-Lite: A Grammar of Multi-View Graphics

Indexed Chart



Focus + Context

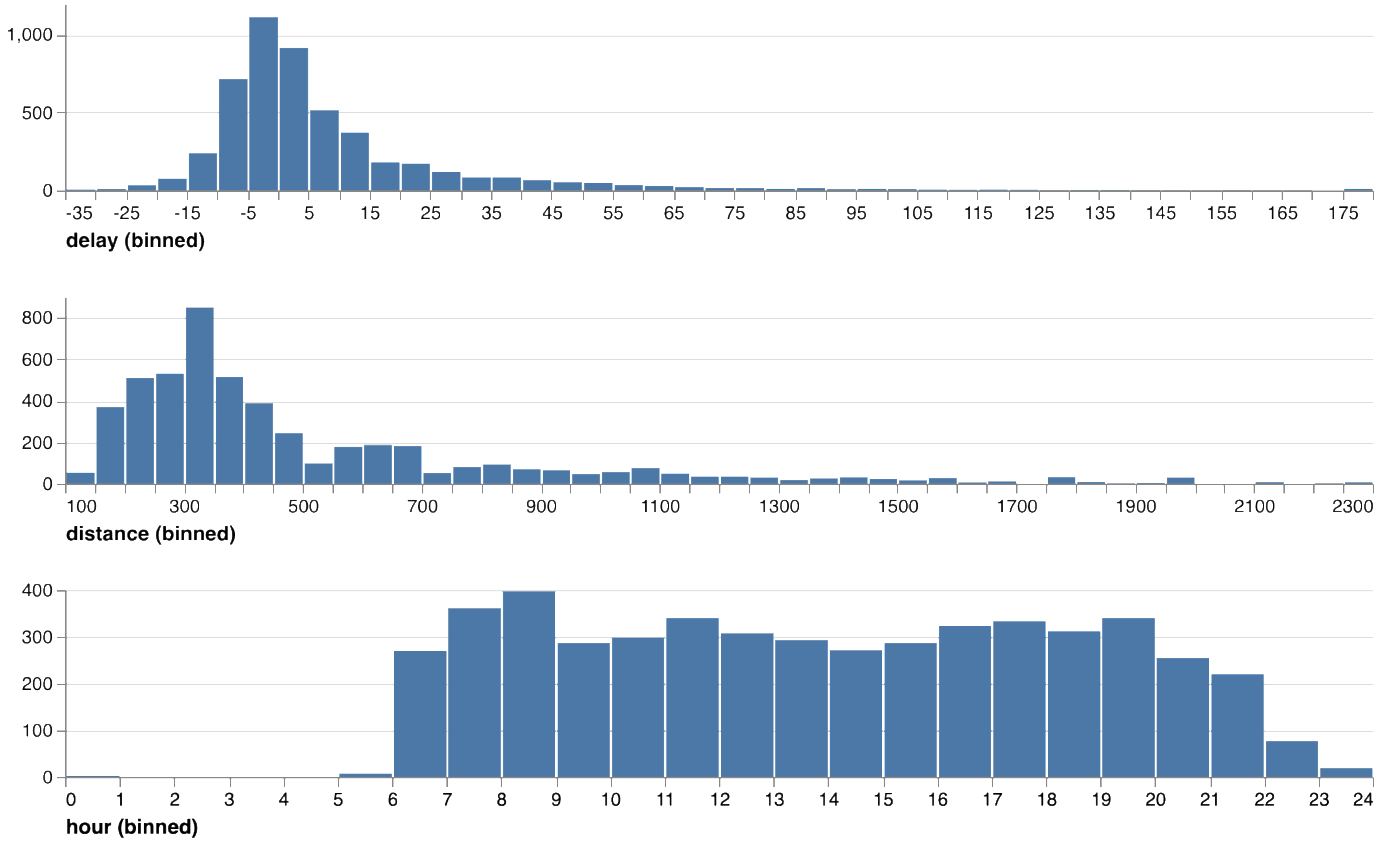




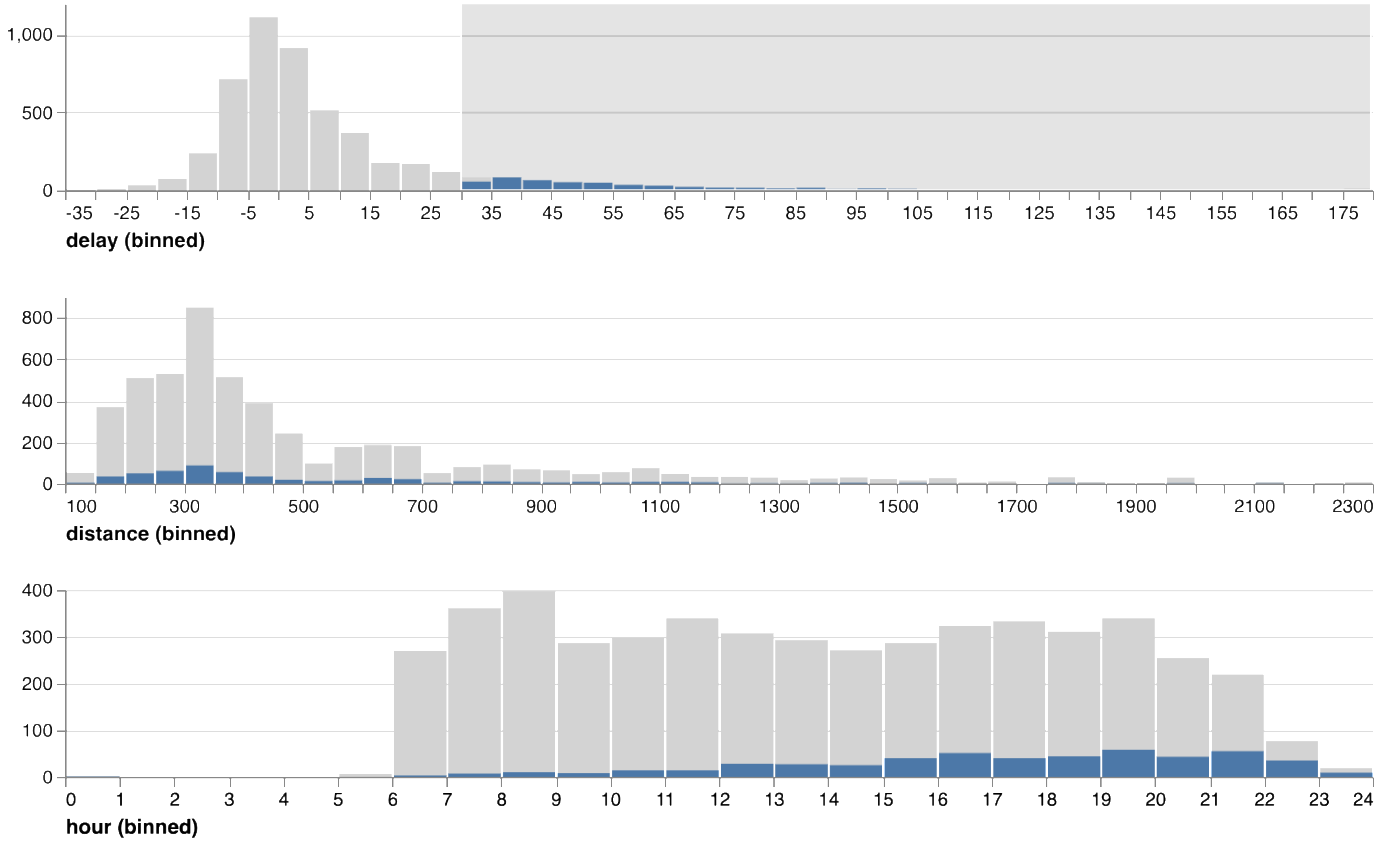
Cross-Filtering

Vega-Lite: A Grammar of Interactive Graphics

Cross-Filtering in Vega-Lite

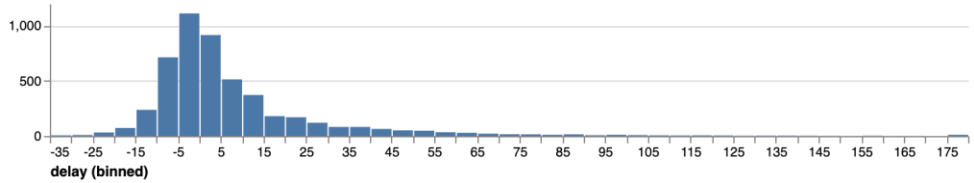


Cross-Filtering in Vega-Lite



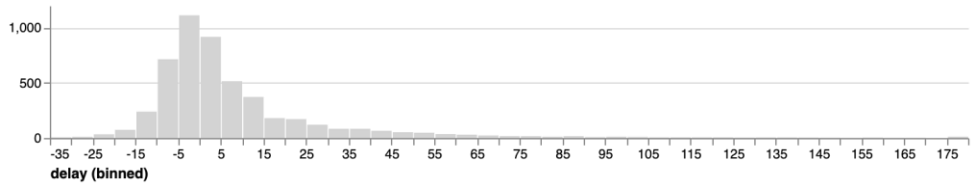
Cross-Filtering in Vega-Lite

```
markBar().encode(
  x().fieldQ('delay').bin(true),
  y().count()
).data('data/flights.json')
```



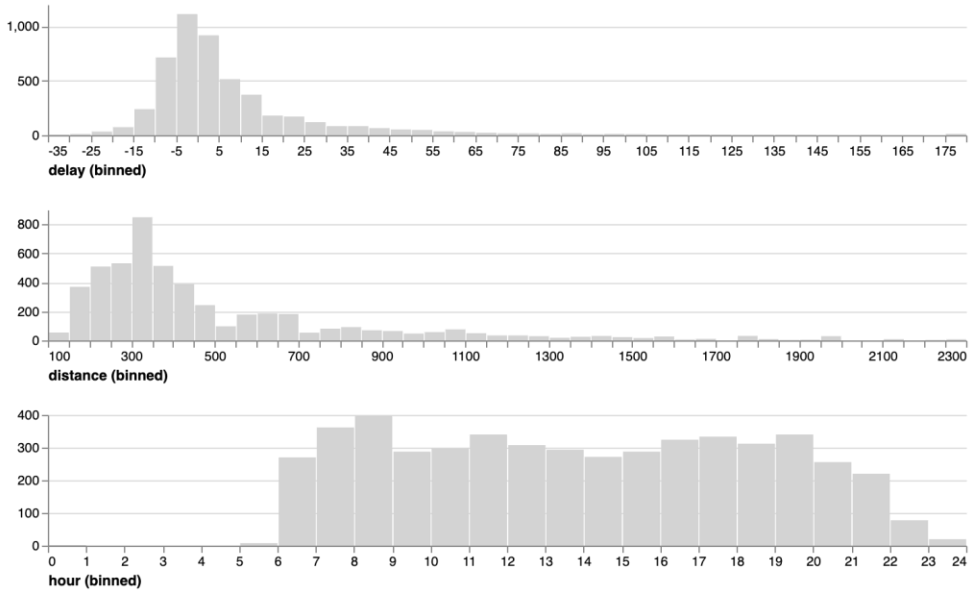
Cross-Filtering in Vega-Lite

```
markBar().encode(
  x().fieldQ('delay').bin(true),
  y().count(),
  color().value('lightgrey')
).data('data/flights.json')
```



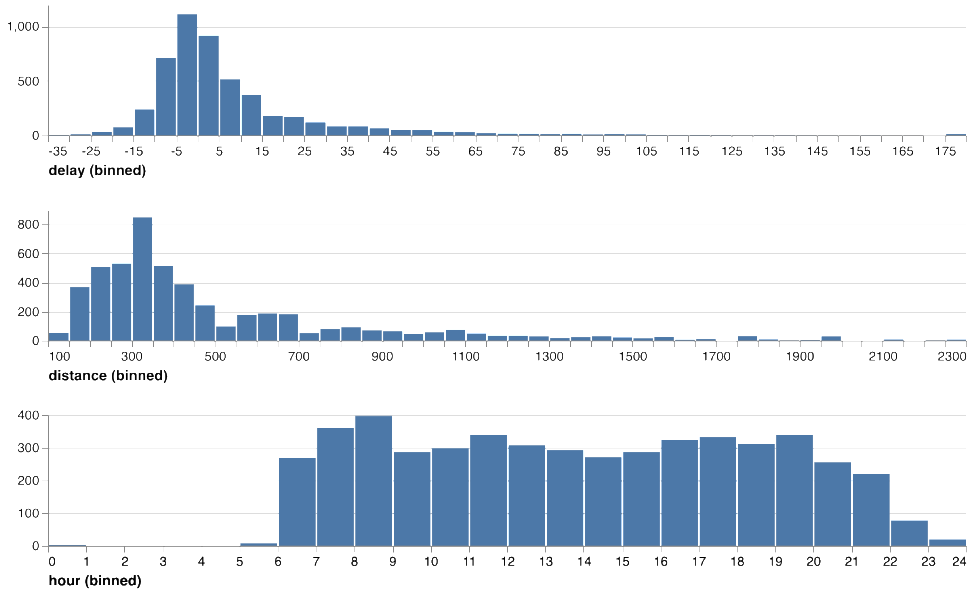
Cross-Filtering in Vega-Lite

```
markBar().encode(
  x().fieldQ(repeat('row').bin(true),
  y().count(),
  color().value('lightgrey')
)
.repeat({
  row: ['delay', 'distance', 'hour']
 })
.data('data/flights.json')
```



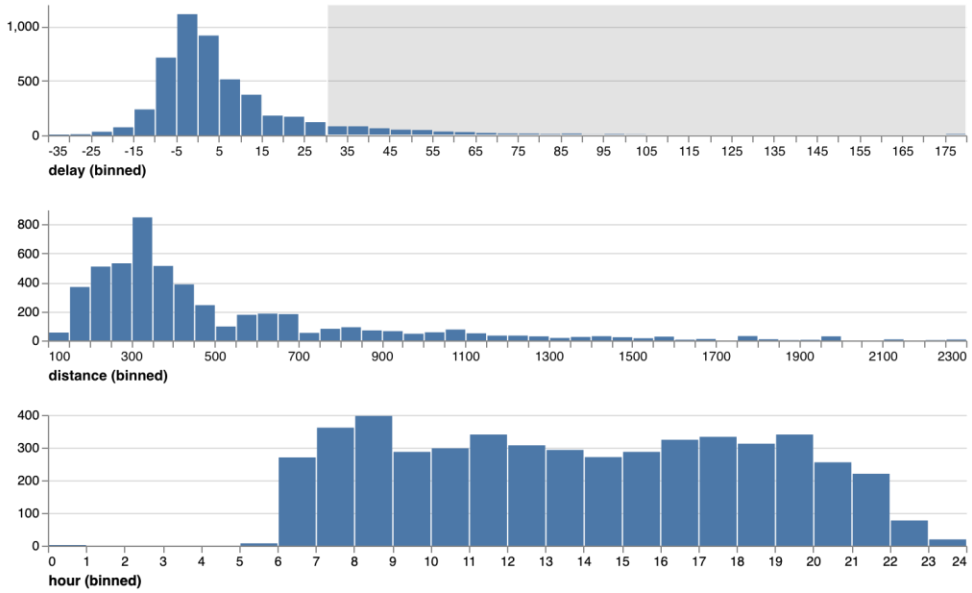
Cross-Filtering in Vega-Lite

```
layer(
  markBar().encode(
    x().fieldQ(repeat('row')).bin(true),
    y().count(),
    color().value('lightgrey')
  ),
  markBar().encode(
    x().fieldQ(repeat('row')).bin(true),
    y().count()
  )
)
.repeat({
  row: ['delay', 'distance', 'hour']
})
.data('data/flights.json')
```



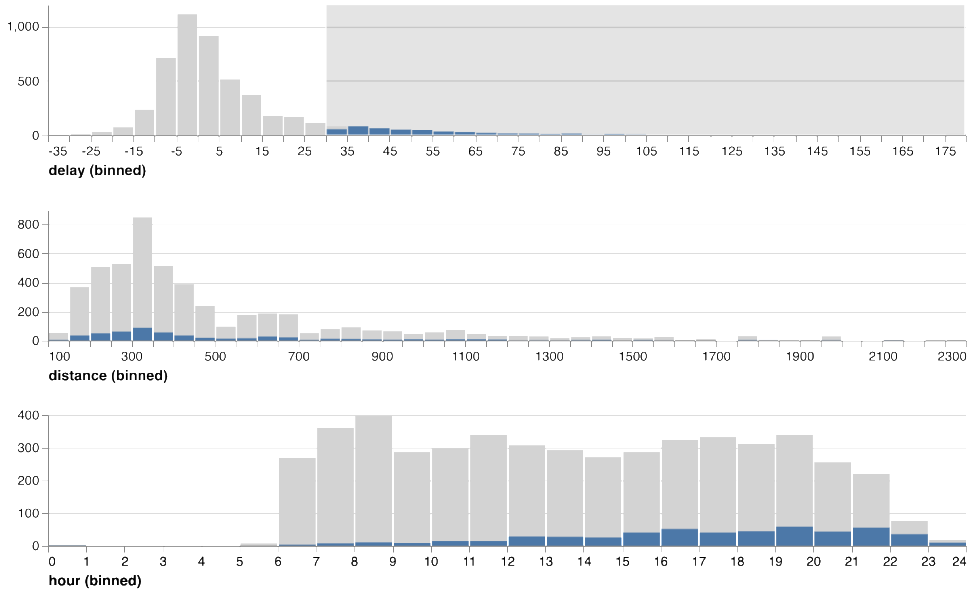
Cross-Filtering in Vega-Lite

```
brush = selectInterval().encodings('x')

layer(
  markBar().encode(
    x().fieldQ(repeat('row')).bin(true),
    y().count(),
    color().value('lightgrey')
  ).params(brush),
  markBar().encode(
    x().fieldQ(repeat('row')).bin(true),
    y().count()
  )
)
.repeat({
  row: ['delay', 'distance', 'hour']
})
.data('data/flights.json')
```



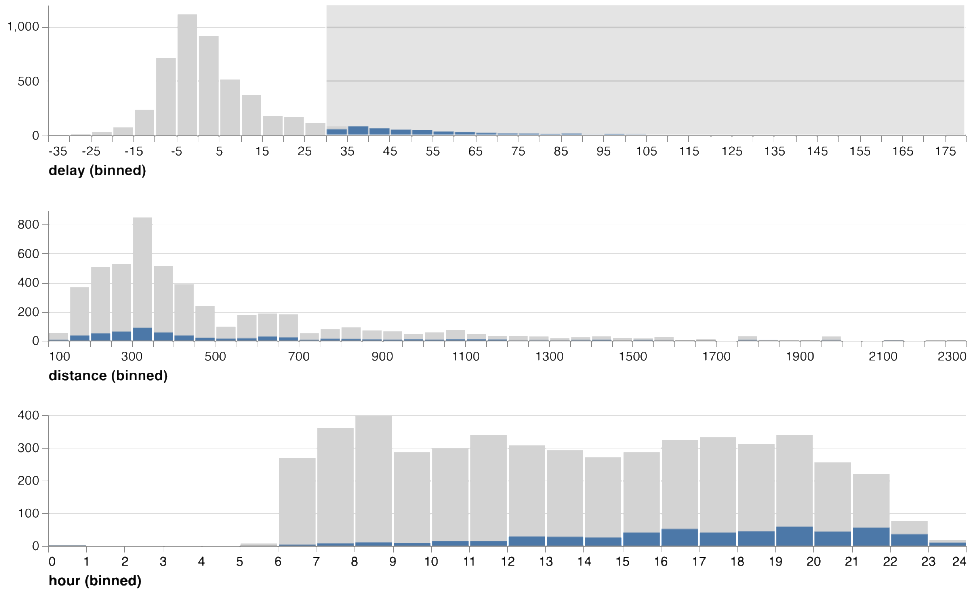
Cross-Filtering in Vega-Lite

```
brush = selectInterval.encodings('x')

layer(
  markBar().encode(
    x().fieldQ(repeat('row')).bin(true),
    y().count(),
    color().value('lightgrey')
  ).params(brush),
  markBar().encode(
    x().fieldQ(repeat('row')).bin(true),
    y().count()
  ).transform(filter(brush))
)
.repeat({
  row: ['delay', 'distance', 'hour']
})
.data('data/flights.json')
```



Cross-Filtering in Vega-Lite

```
brush = selectInterval.encodings('x')

layer(
  markBar().encode(
    x().fieldQ(repeat('row')).bin(true),
    y().count(),
    color().value('lightgrey')
  ).params(brush),
  markBar().encode(
    x().fieldQ(repeat('row')).bin(true),
    y().count()
  ).transform(filter(brush))
)
.repeat({
  row: ['delay', 'distance', 'hour']
})
.data('data/flights.json')
```



Multi-view interactive graphics in ~10 lines of code

What constitutes a selection?

Input handlers: click, shift-click, drag, zoom, …

Bindings

- Inputs: interactive brush, query widgets
- Axis scales: pan / zoom a scale domain
- Legends: interactive selection

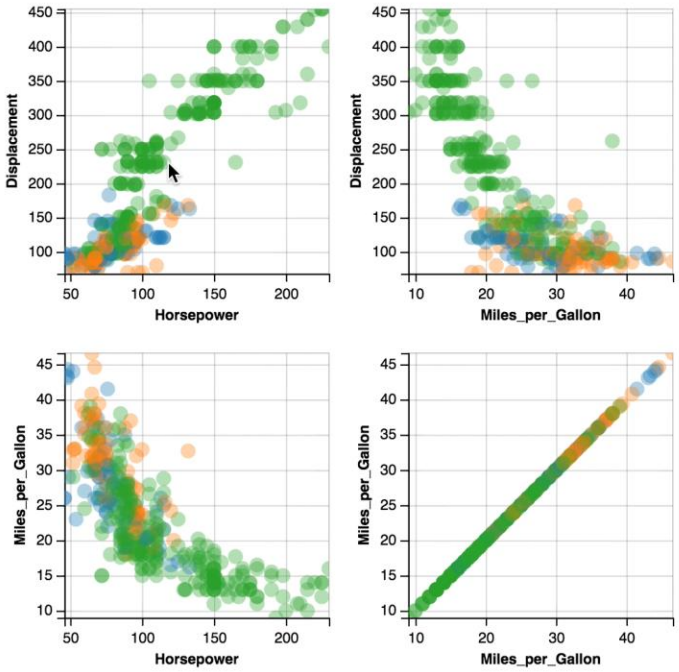
Scale inversion: visual space → data space

Predicate: test if a data record is selected

A selection can then *parameterize* data transformations and visual encodings.

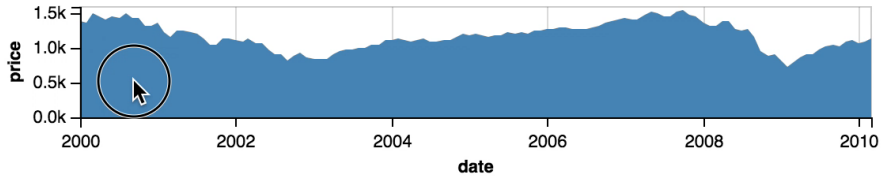
Selections

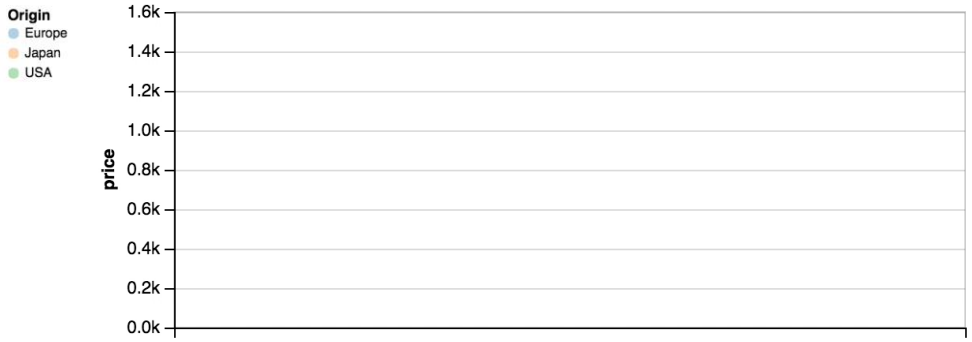
Selections ***invert*** scales and ***parameterize*** graphics

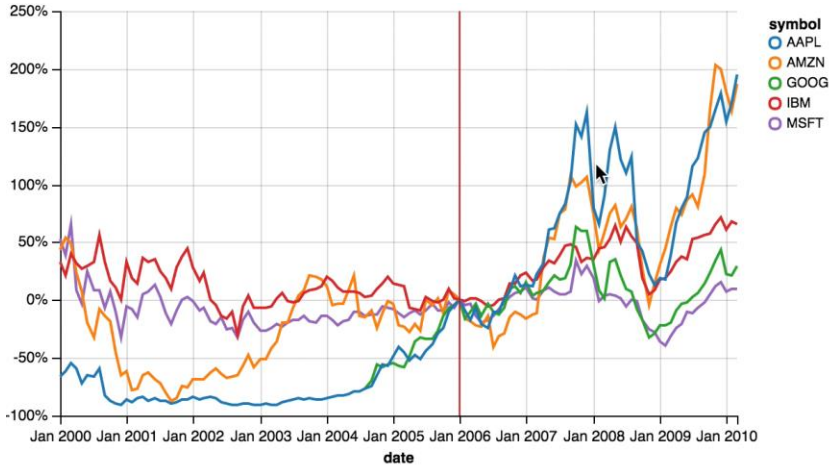


Bind selection to scale domains:
Synchronized Pan & Zoom!

Overview + Detail







Parameterized Transformations