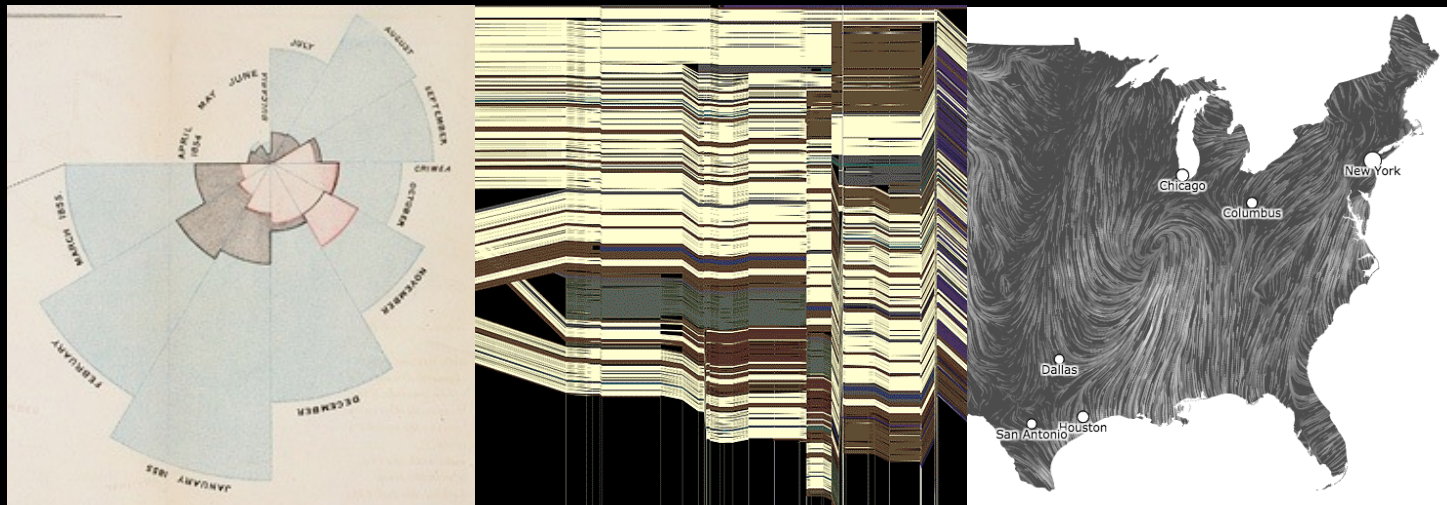


CSE 442 - Data Visualization

Interaction



Jeffrey Heer University of Washington

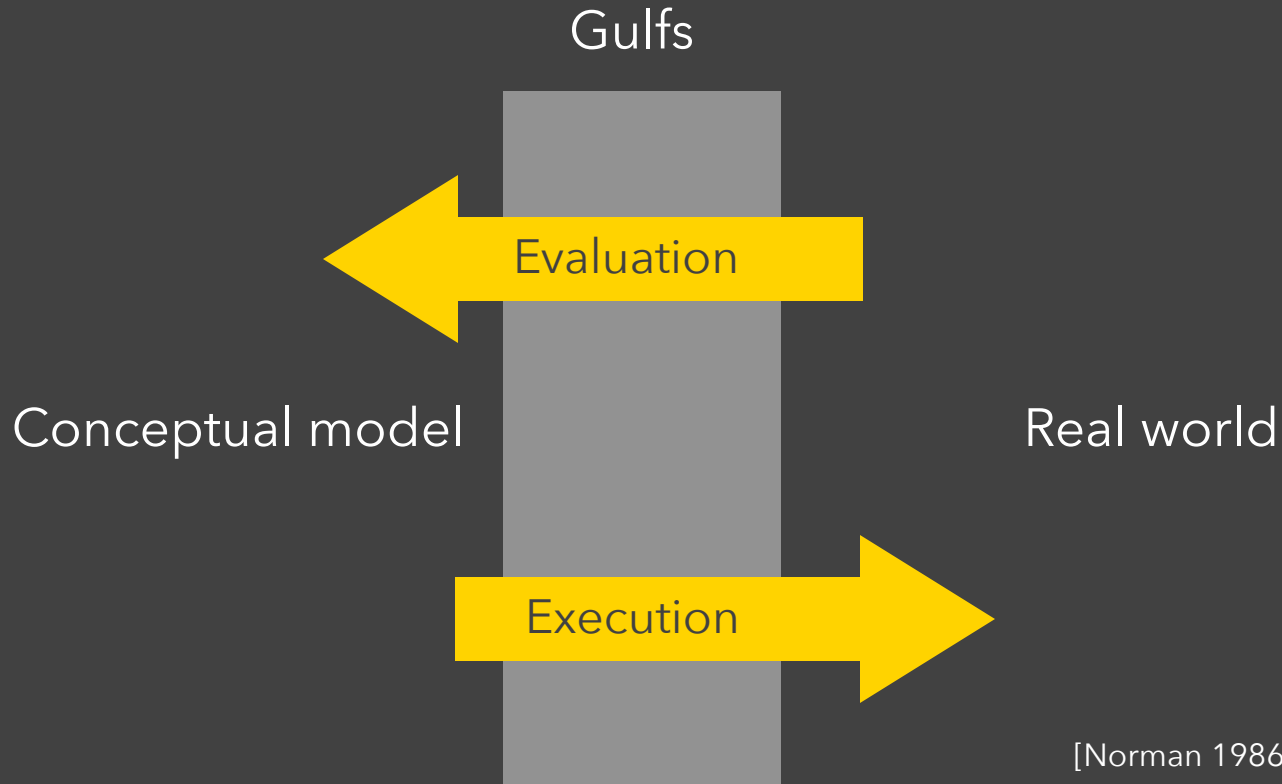
[There is an] apparent challenge that computational artifacts pose to the longstanding distinction between the physical and the social, in the special sense of those things that one designs, builds, and uses, on the one hand, and those things with which one communicates, on the other.

“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



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.

Gulf of Evaluation

Gulf



Conceptual model:
x, y related?

Real world:

x	y
0.67	0.79
0.32	0.63
0.39	0.72
0.27	0.85
0.71	0.43
0.63	0.09
0.03	0.03
0.20	0.54
0.51	0.38
0.11	0.33
0.46	0.46

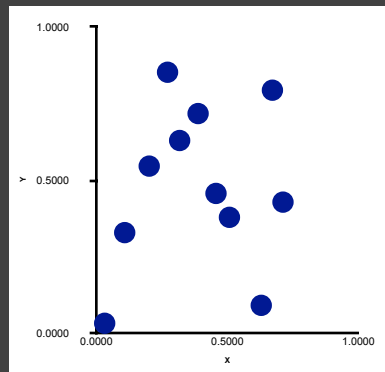
Gulf of Evaluation

Gulf

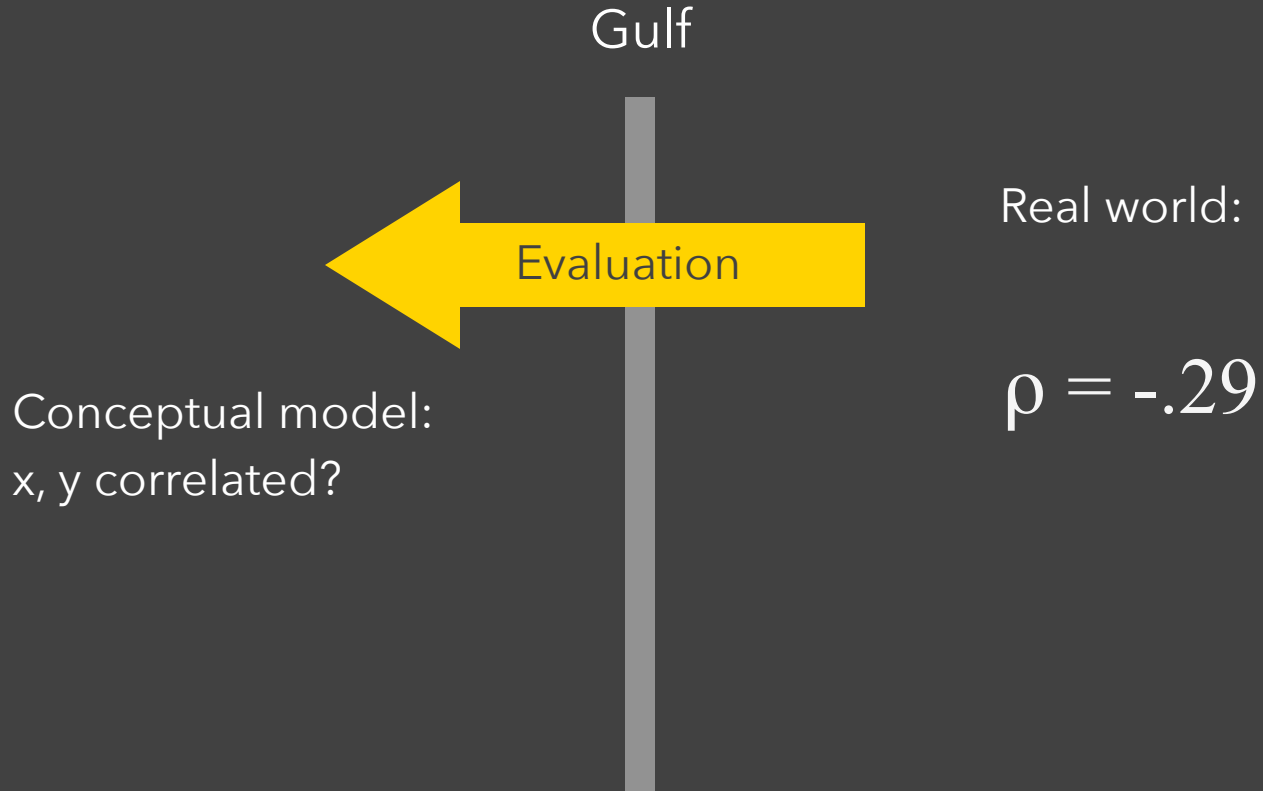
Evaluation

Conceptual model:
 x, y related?

Real world:



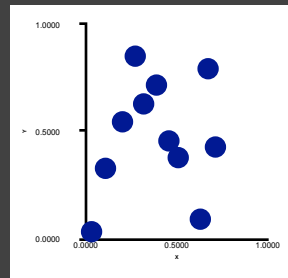
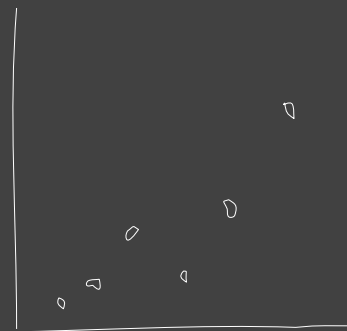
Gulf of Evaluation



Gulf of Execution

Gulf

Conceptual model:
Draw a scatterplot



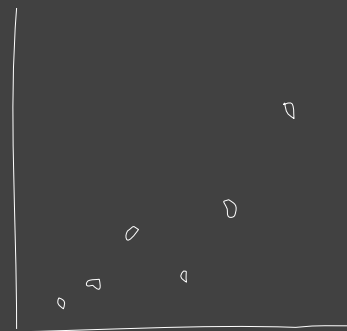
Real world

Move 90 30
Rotate 35
Pen down
...

Execution

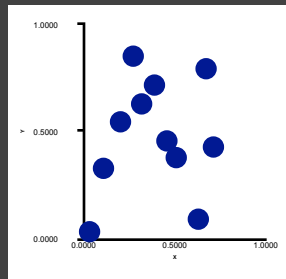
Gulf of Execution

Conceptual model:
Draw a scatterplot



Gulf

Execution



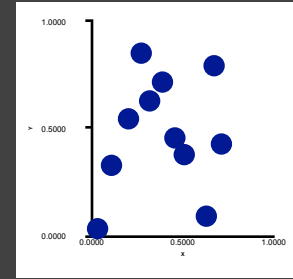
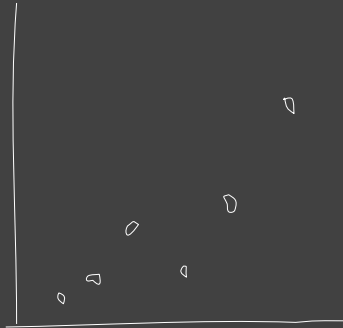
Real world

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

Gulf of Execution

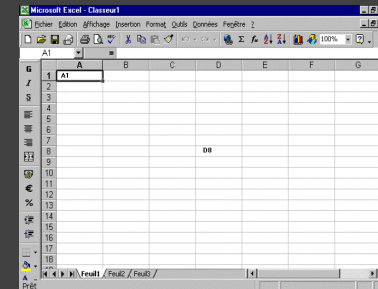
Gulf

Conceptual model:
Draw a scatterplot



Real world

Execution



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.

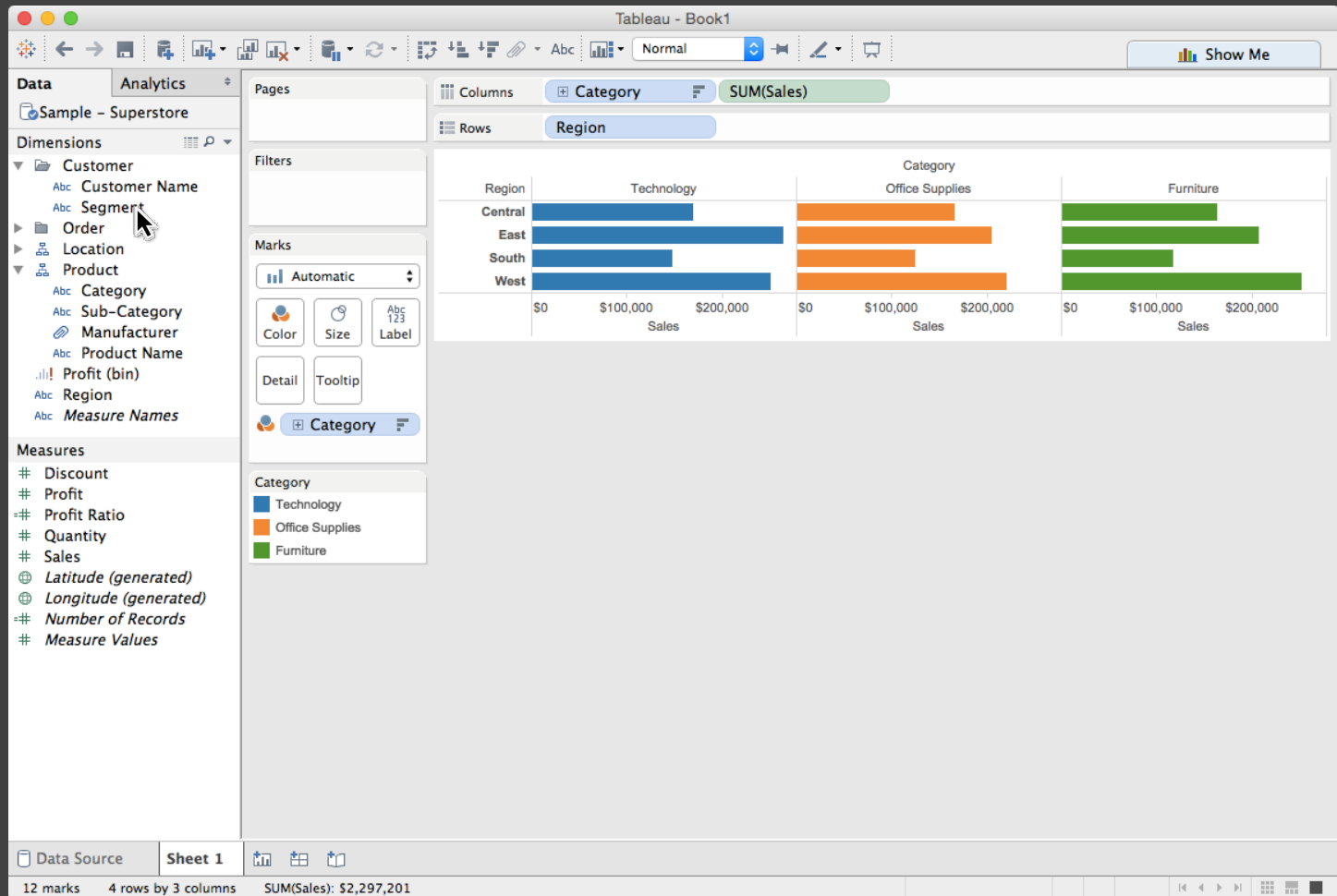
Interactive Visualization

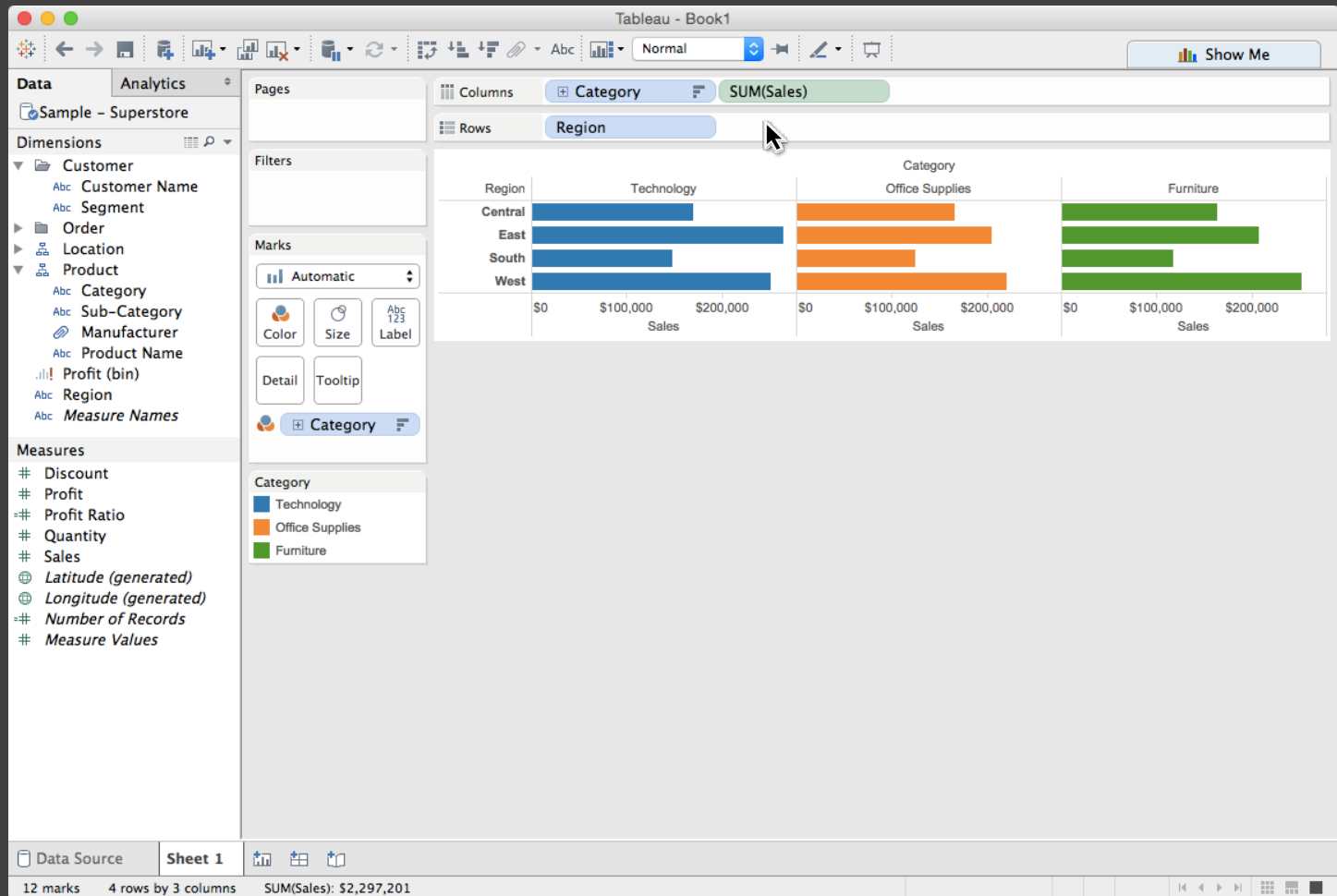
Taxonomy of Interactions

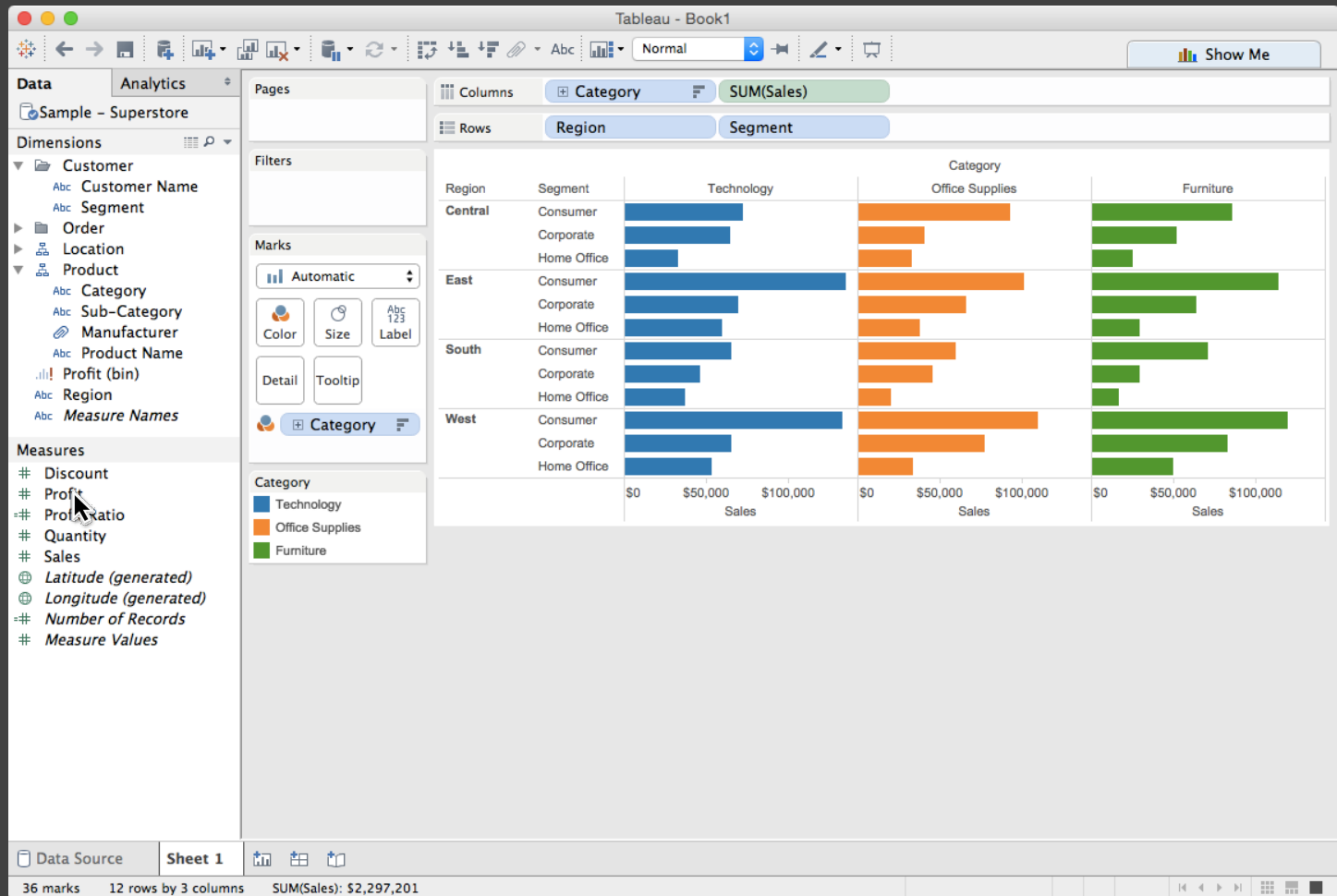
Taxonomy of Interactions

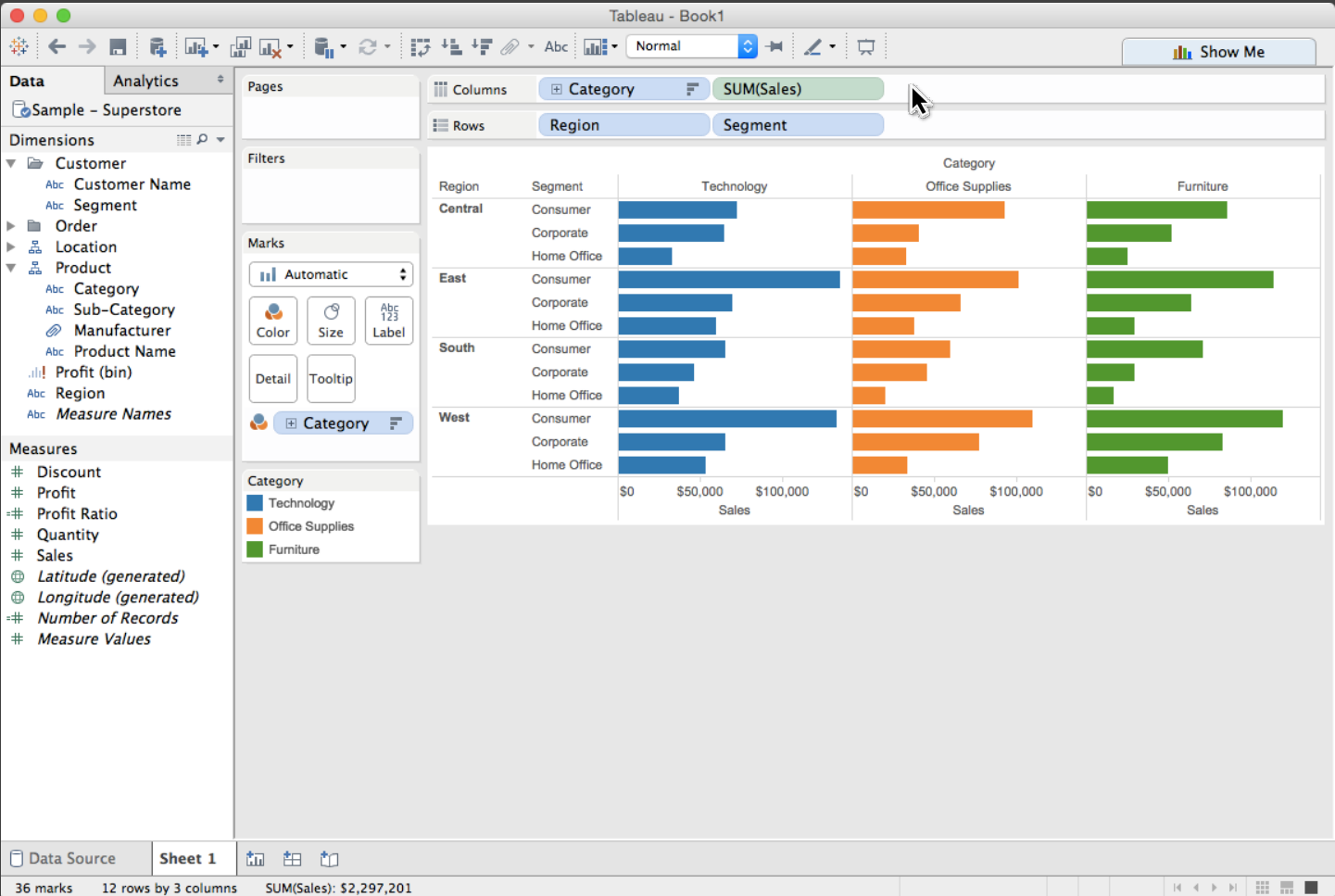
Data and View Specification

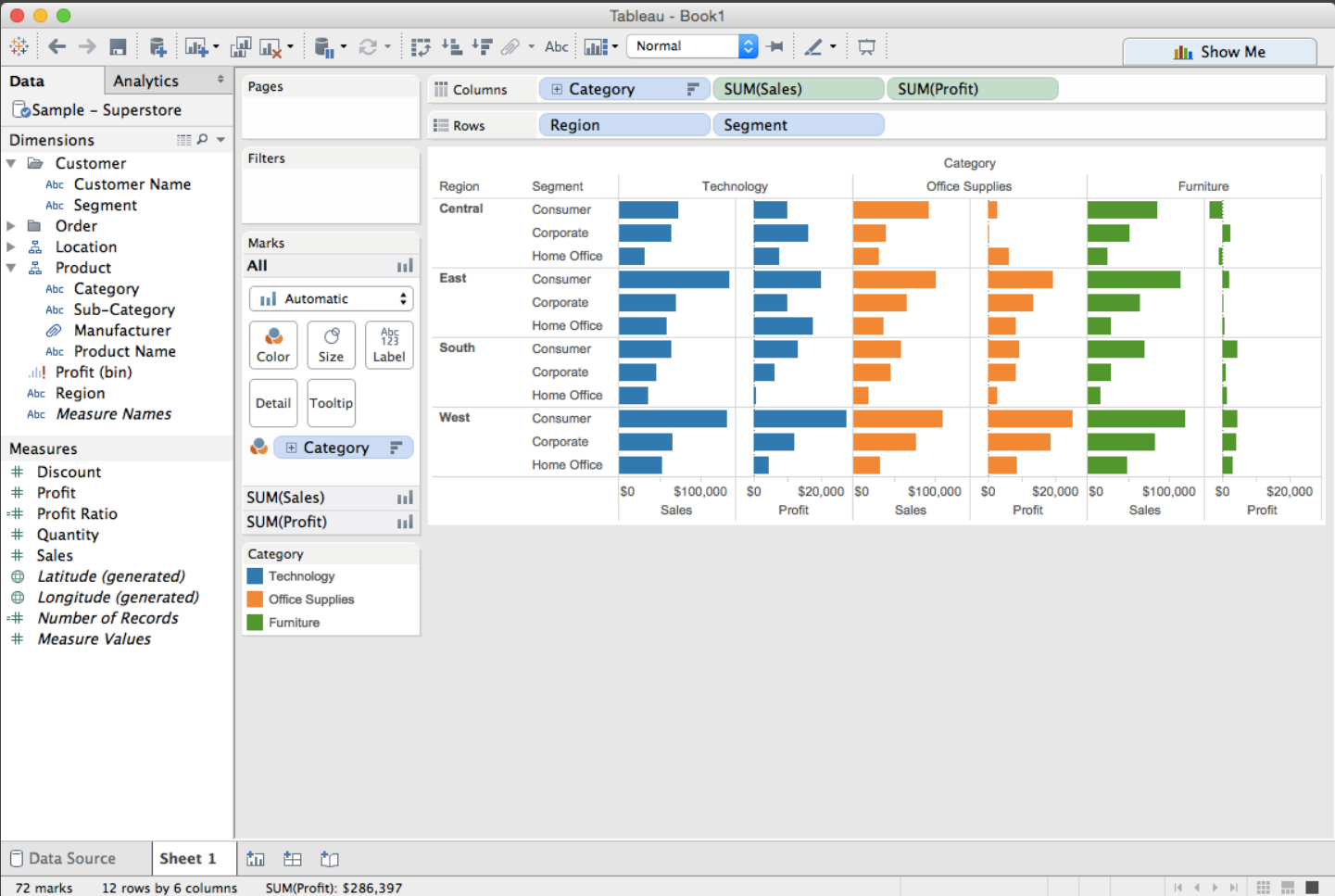
Visualize, Filter, Sort, Derive













Show Me

Columns

Category

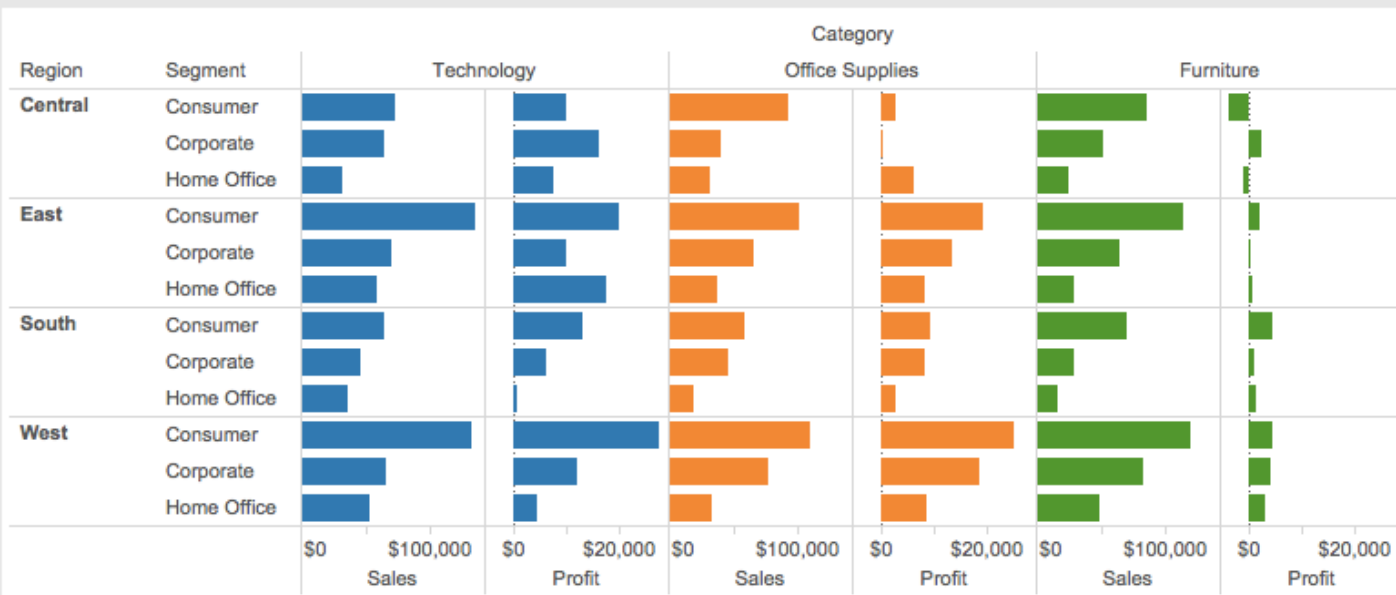
SUM(Sales)

+ SUM(Profit)

Rows

Region

Segment



SUM(Sales)

SUM(Profit)

Category

Technology

Office Supplies

Furniture

Taxonomy of Interactions

Data and View Specification

Visualize, Filter, Sort, Derive

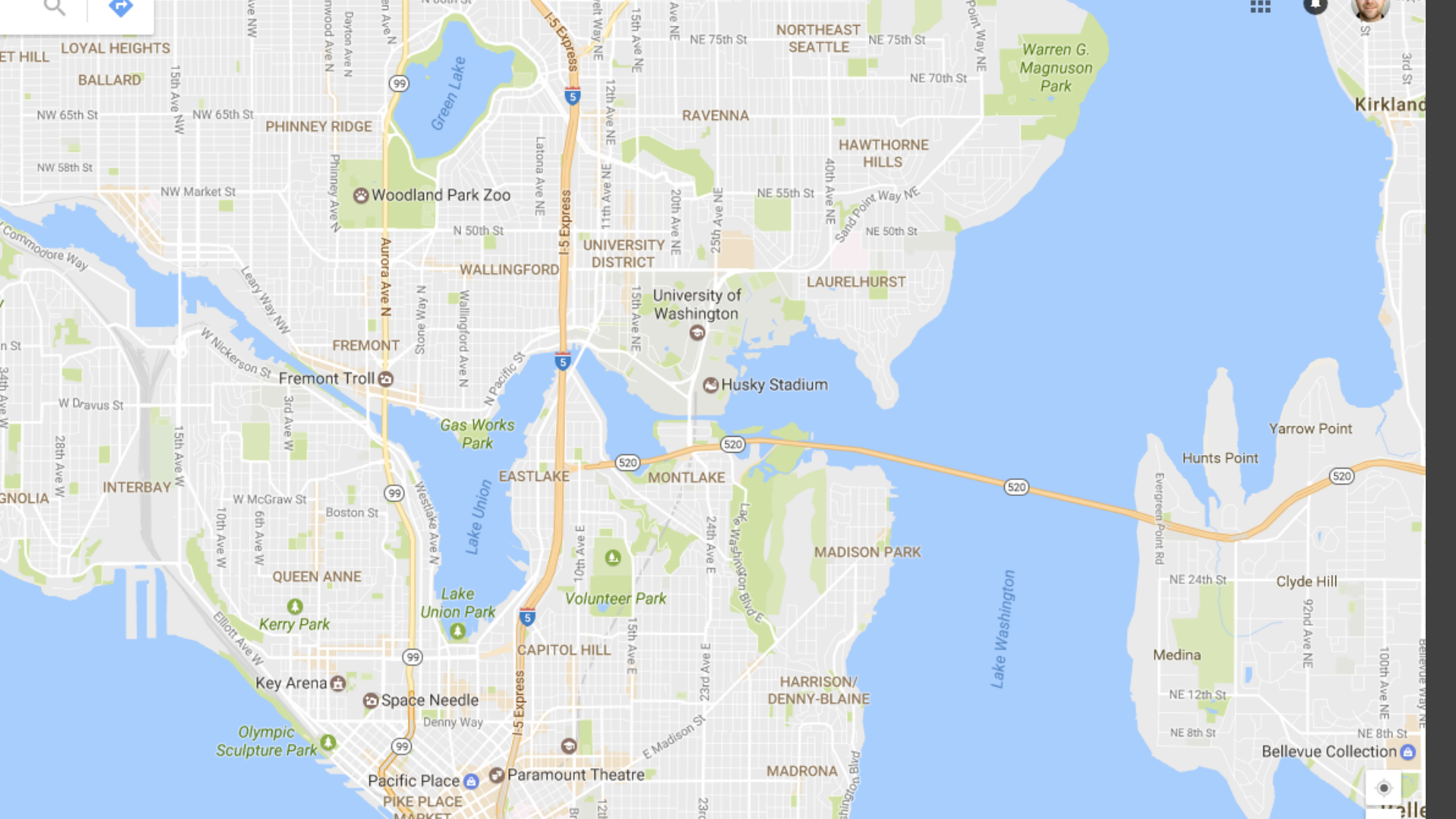
Taxonomy of Interactions

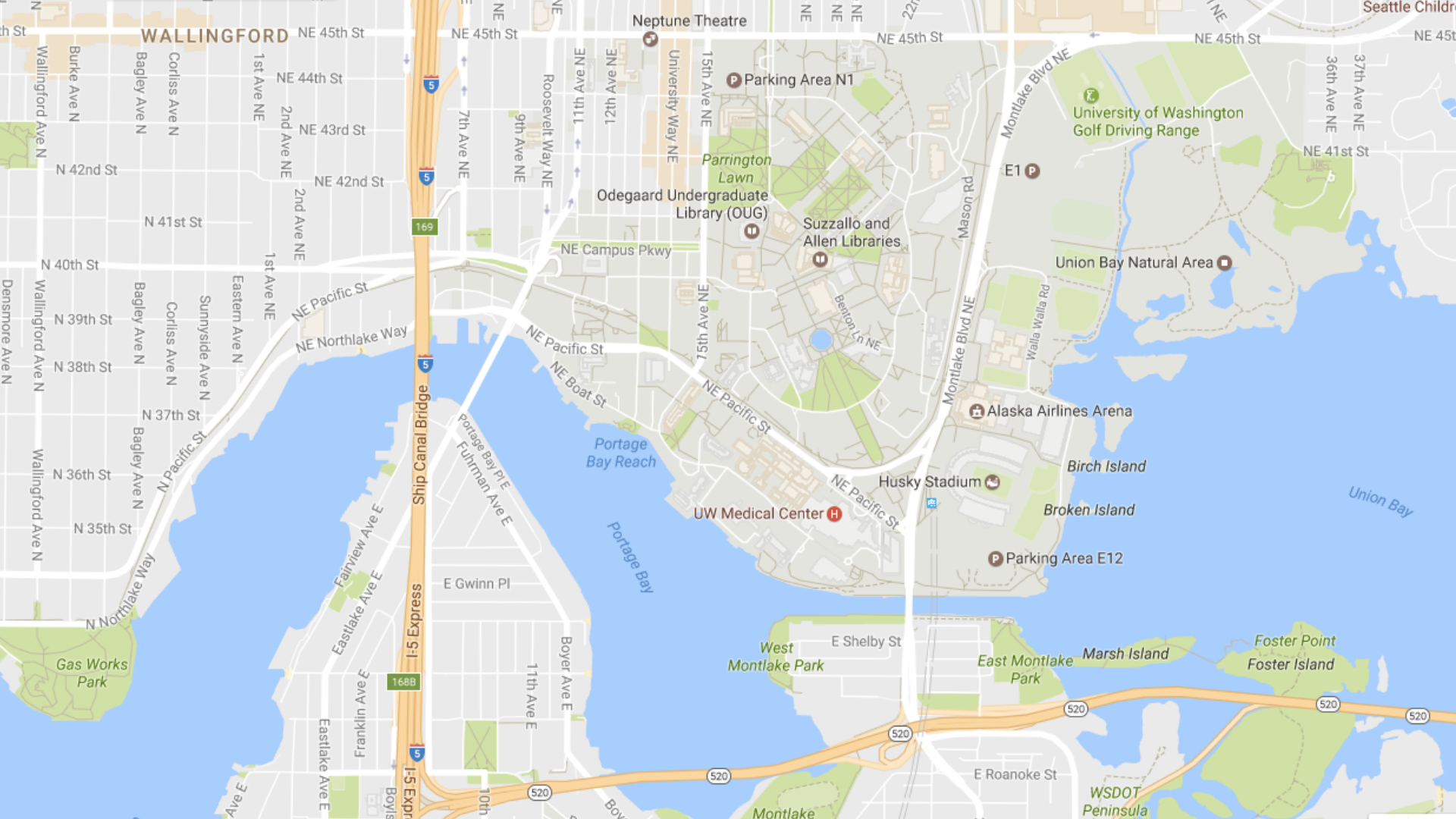
Data and View Specification

Visualize, Filter, Sort, Derive

View Manipulation

Select, Navigate, Coordinate, Organize





Taxonomy of Interactions

Data and View Specification

Visualize, Filter, Sort, Derive

View Manipulation

Select, Navigate, Coordinate, Organize

Taxonomy of Interactions

Data and View Specification

Visualize, Filter, Sort, Derive

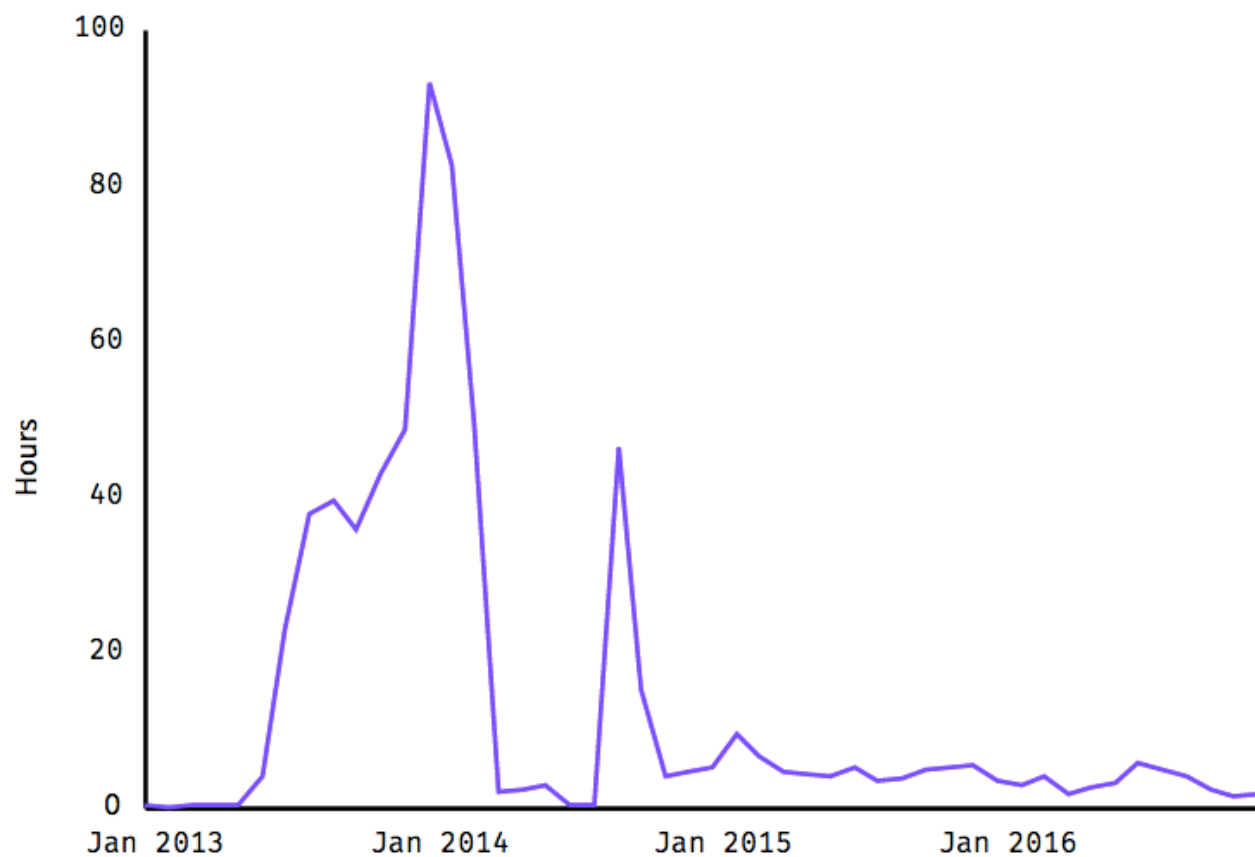
View Manipulation

Select, Navigate, Coordinate, Organize

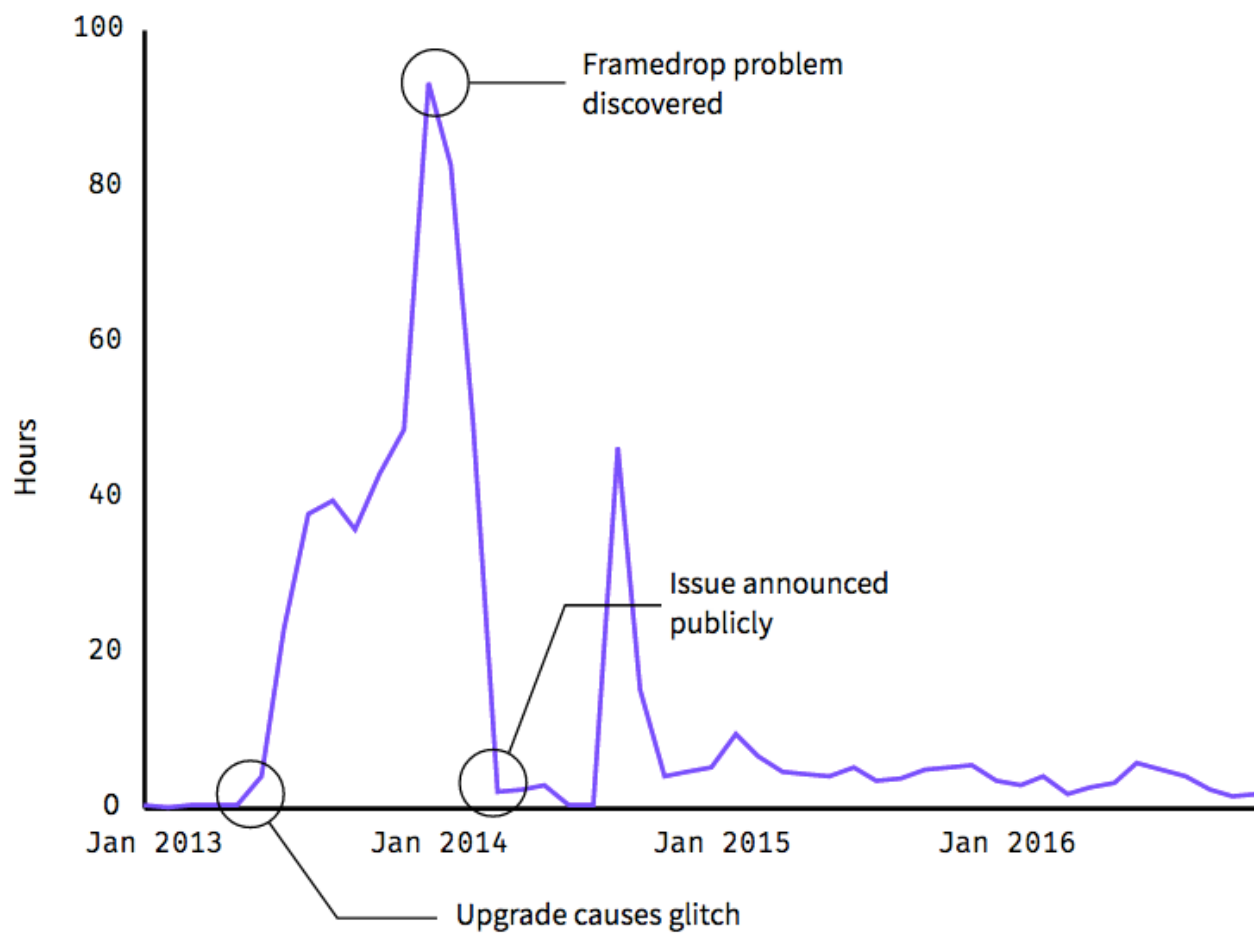
Process and Provenance

Record, Annotate, Share, Guide

Hours of footage lost each month due to dropped frames



Hours of footage lost each month due to dropped frames



Taxonomy of Interactions

Data and View Specification

Visualize, Filter, Sort, Derive

View Manipulation

Select, Navigate, Coordinate, Organize

Process and Provenance

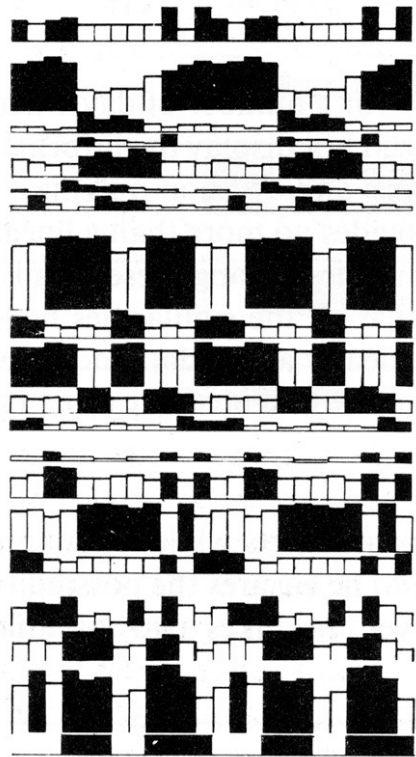
Record, Annotate, Share, Guide

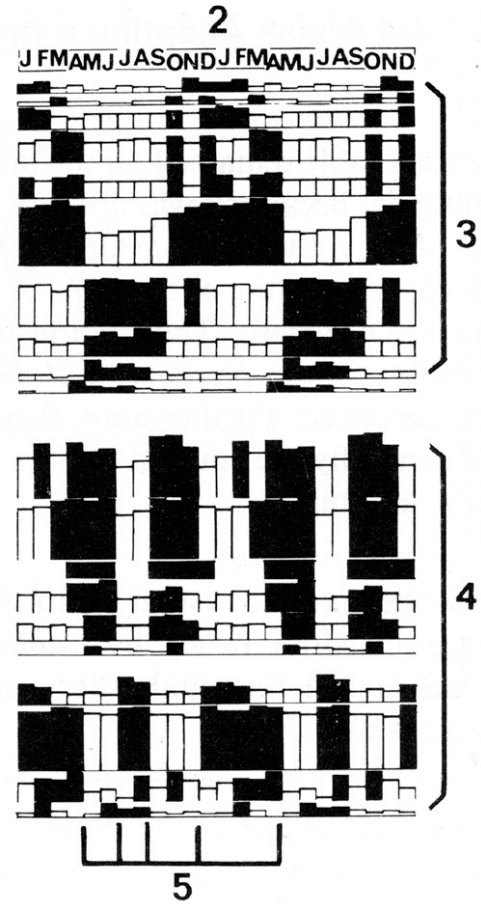
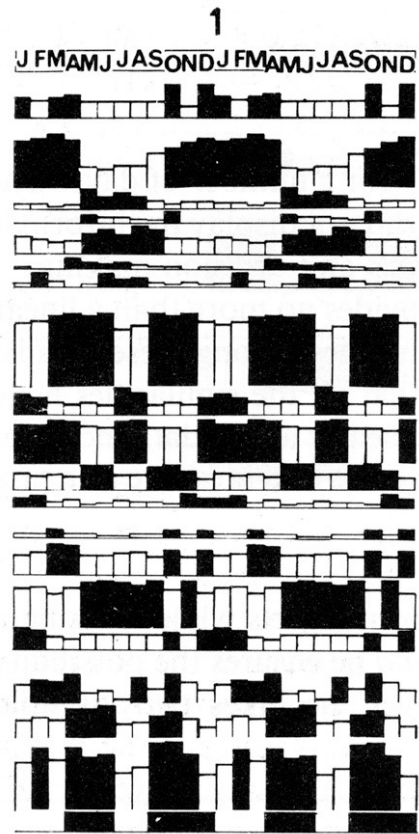
EXAMPLE:
Bertin's Hotel Data

J	F	M	A	M	J	J	A	S	O	N	D		
26	21	26	28	20	20	20	20	20	40	15	40	1	% CLIENTELE FEMALE
69	70	77	71	37	36	39	39	55	60	68	72	2	% —"—— LOCAL
7	6	3	6	23	14	19	14	9	6	8	8	3	% —"—— U.S.A.
0	0	0	0	8	6	6	4	2	12	0	0	4	% —"—— SOUTH AMERICA
20	15	14	15	23	27	22	30	27	19	19	17	5	% —"—— EUROPE
1	0	0	8	6	4	6	4	2	1	0	1	6	% —"—— M.EAST, AFRICA
3	10	6	0	3	13	8	9	5	2	5	2	7	% —"—— ASIA
78	80	85	86	85	87	70	76	87	85	87	80	8	% BUSINESSMEN
22	20	15	14	15	13	30	24	13	15	13	20	9	% TOURISTS
70	70	75	74	69	68	74	75	68	68	64	75	10	% DIRECT RESERVATIONS
20	18	19	17	27	27	19	19	26	27	21	15	11	% AGENCY —"——
10	12	6	9	4	5	7	6	6	5	15	10	12	% AIR CREWS
2	2	4	2	2	1	1	2	2	4	2	5	13	% CLIENTS UNDER 20 YEARS
25	27	37	35	25	25	27	28	24	30	24	30	14	% —"—— 20-35 —"——
48	49	42	48	54	55	53	57	55	46	55	43	15	% —"—— 35-55 —"——
25	22	17	15	19	19	19	19	19	20	19	22	16	% —"—— MORE THAN 55 —"——
163	167	166	174	152	155	145	170	157	174	165	156	17	PRICE OF ROOMS
1.65	1.71	1.65	1.91	1.90	2.	1.54	1.60	1.73	1.82	1.66	1.44	18	LENGTH OF STAY
67	82	70	83	74	77	56	62	90	92	78	55	19	% OCCUPANCY
			X	X	X			X	X	X	X	20	CONVENTIONS

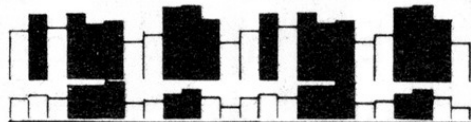
1

J F M A M J J A S O N D J F M A M J J A S O N D





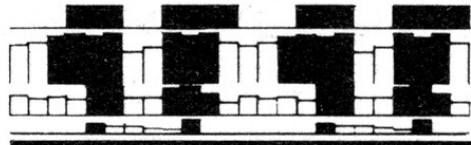
J F M A M J J A S O N D J F M A M J J A S O N D



10 % OCCUPANCY

18 LENGTH OF STAY

ACTIVE AND
SLOW PERIODS



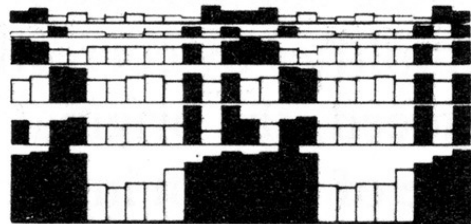
20 CONVENTIONS

8 BUSINESSMEN

11 AGENCY RESERVATIONS

4 SOUTH AMERICA

DISCOVERY FACTORS



18 AIR CREWS

18 CLIENTS UNDER 20 YEARS

10 CLIENTS MORE THAN 55 YEARS

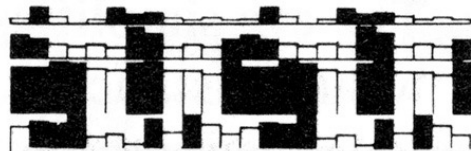
14 CLIENTS FROM 20-35 YEARS

1 FEMALE CLIENTELE

2 LOCAL CLIENTELE

RECOVERY FACTORS

WINTER



7 ASIA

9 TOURISTS

10 DIRECT RESERVATION

17 PRICE OF ROOMS

WINTER-SUMMER



6 MIDDLE EAST, AFRICA

3 U. S. A.

5 EUROPE

15 CLIENTS FROM 35-55 YEARS

SUMMER



[Graphics and Graphic Information Processing, Bertin 81]



[Graphics and Graphic Information Processing, Bertin 81]



[Graphics and Graphic Information Processing, Bertin 81]

EXAMPLE:
Tukey et al.'s PRIM-9



PRIM-9, Tukey, Fisherkeller, Friedman 1972

Selection

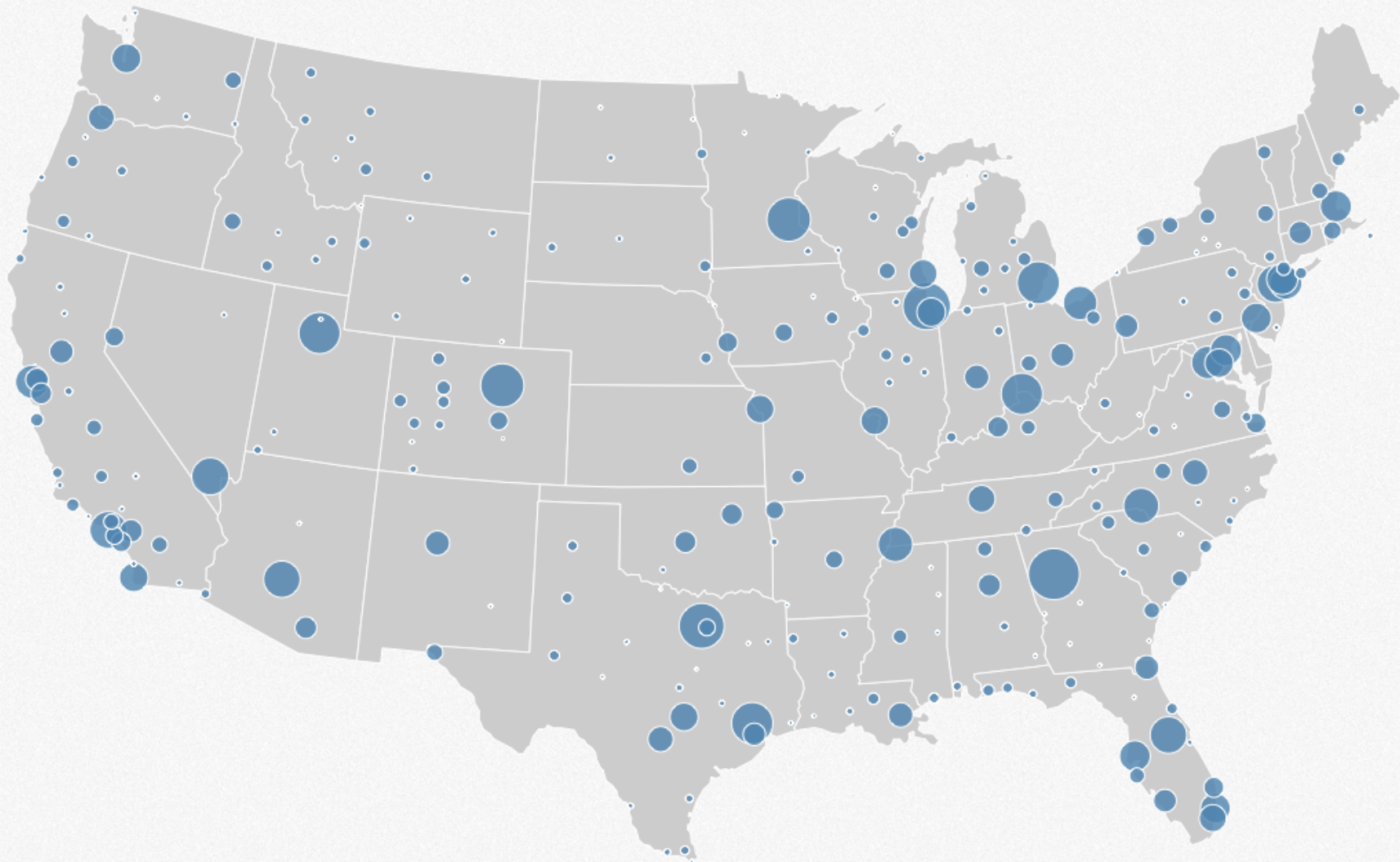
Basic Selection Methods

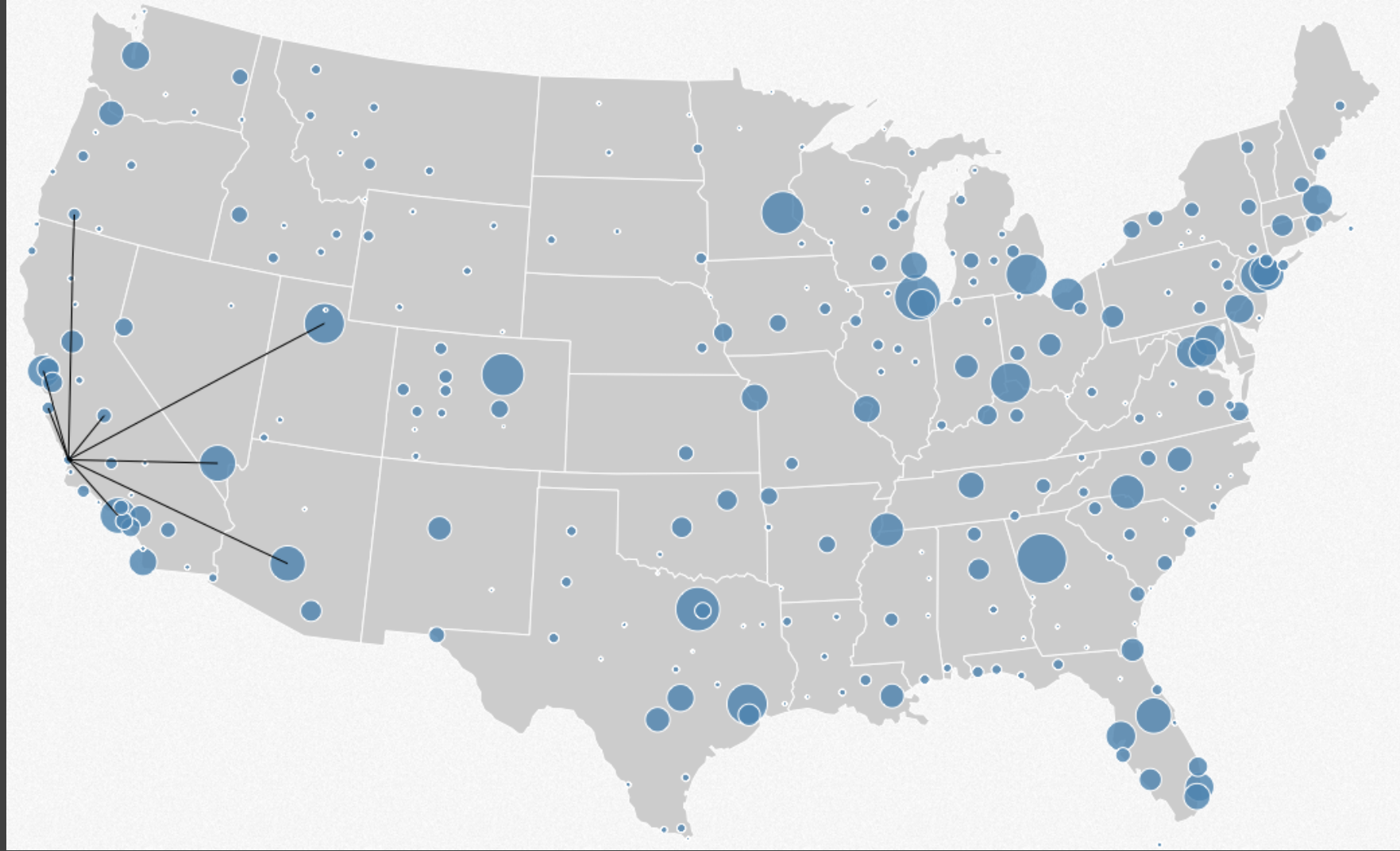
Point Selection

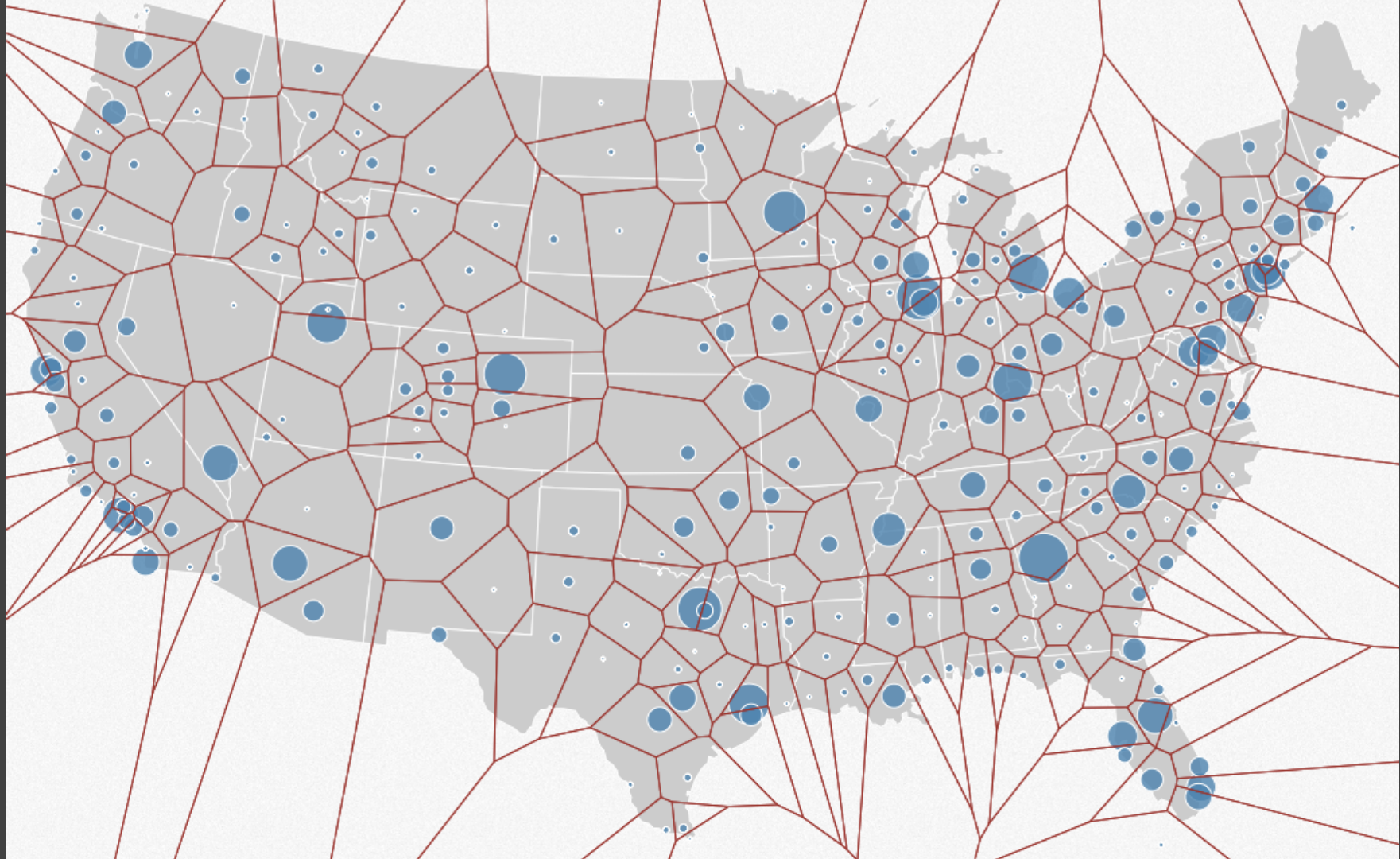
Mouse Hover / Click

Touch / Tap

Select Nearby Element (e.g., Bubble Cursor)







Basic Selection Methods

Point Selection

Mouse Hover / Click

Touch / Tap

Select Nearby Element (e.g., Bubble Cursor)

Region Selection

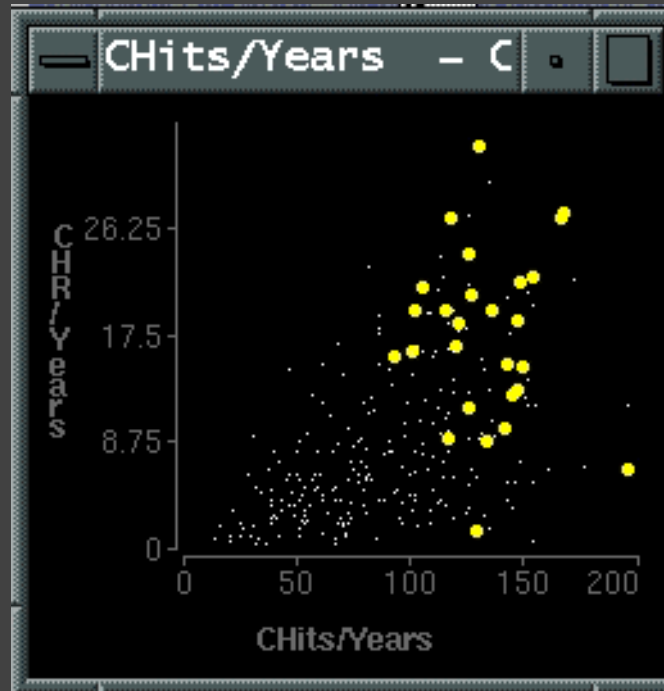
Rubber-band (rectangular) or Lasso (freehand)

Area cursors ("brushes")

Brushing & Linking

Brushing

Direct attention to a subset of data [Wills 95]



Brushing & Linking

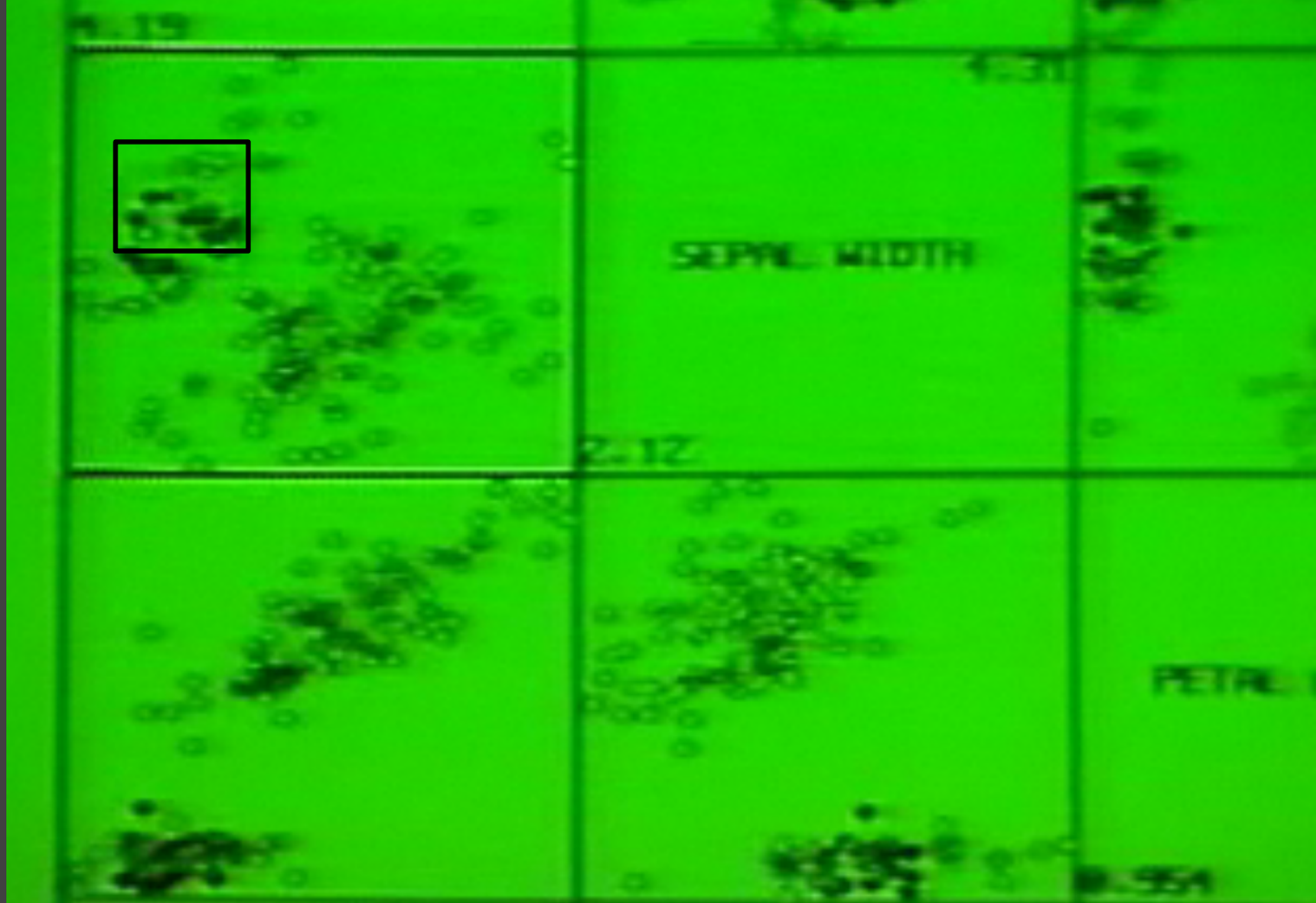
Select ("***brush***") a subset of data

See selected data in other views

The components must be ***linked***

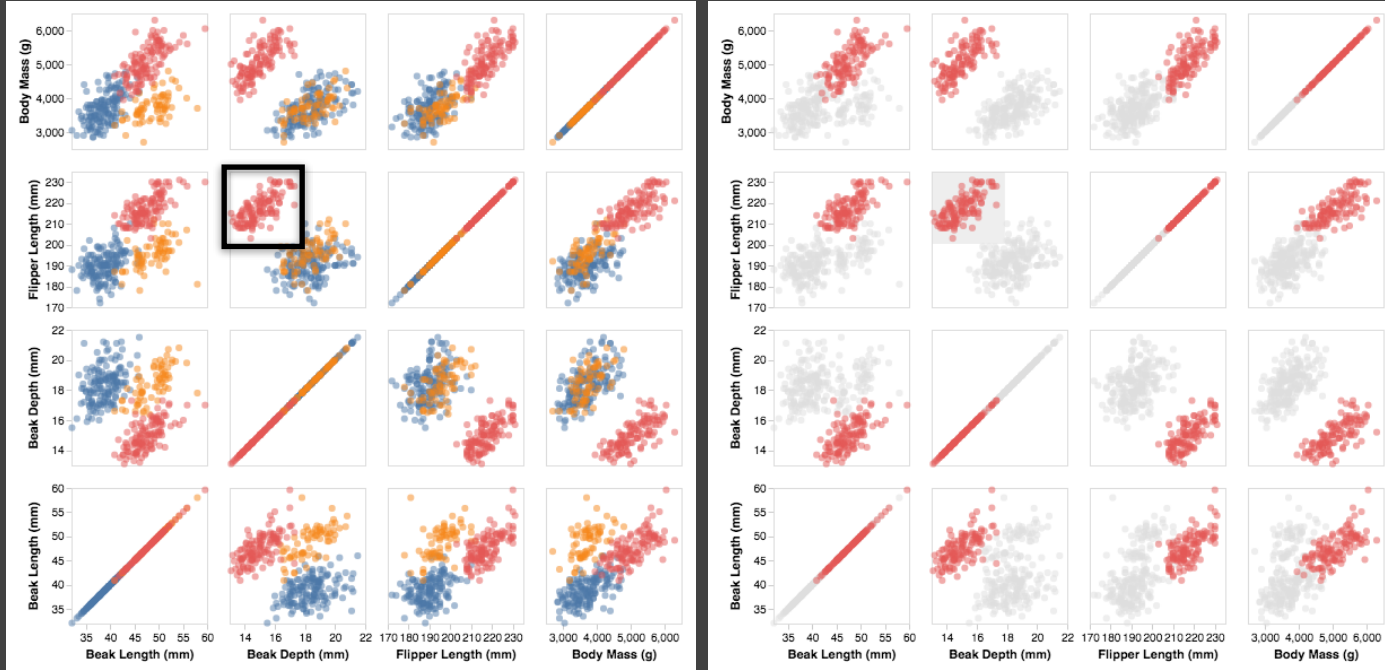
by *tuple* (matching data points), or

by *query* (matching range or values)



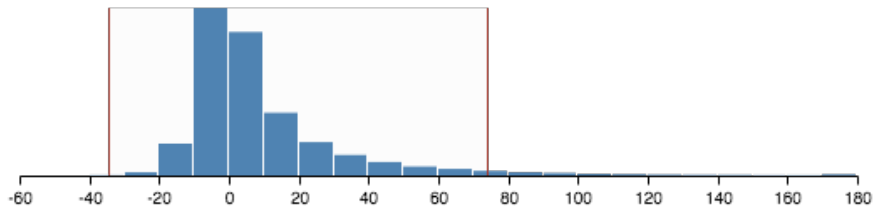
Brushing Scatterplots, Becker & Cleveland 1982

Brushing Scatterplots

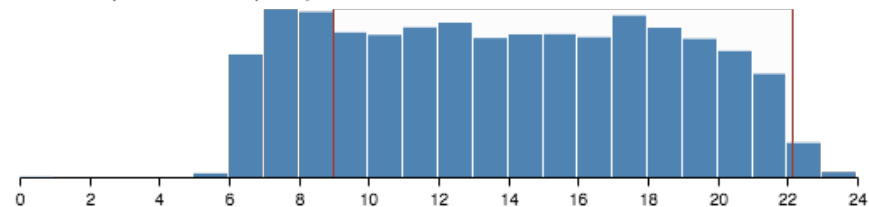


Cross-Filtering

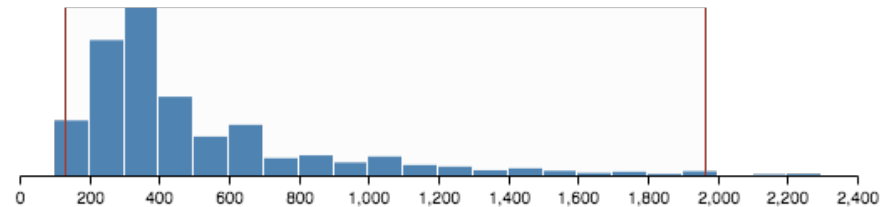
Arrival Delay (min)



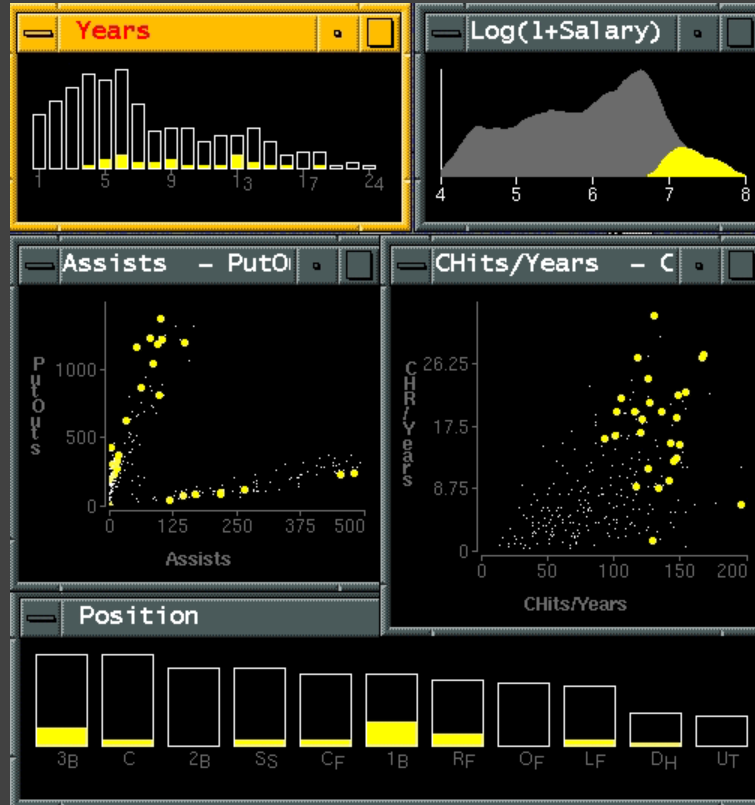
Local Departure Time (hour)



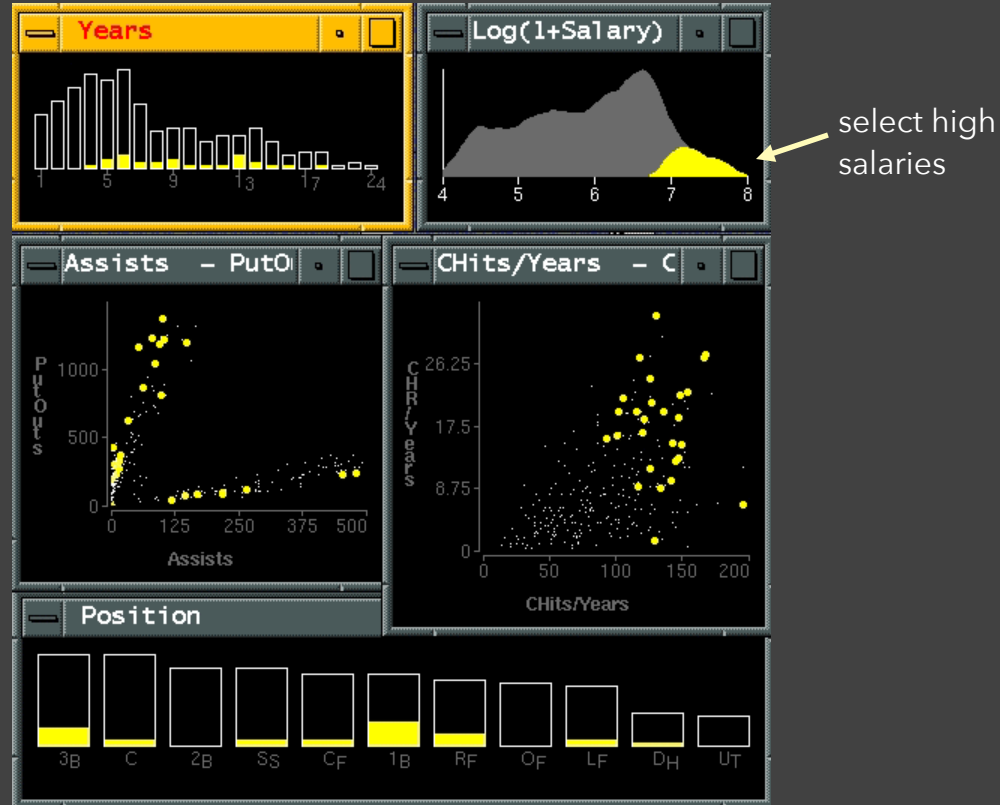
Travel Distance (miles)



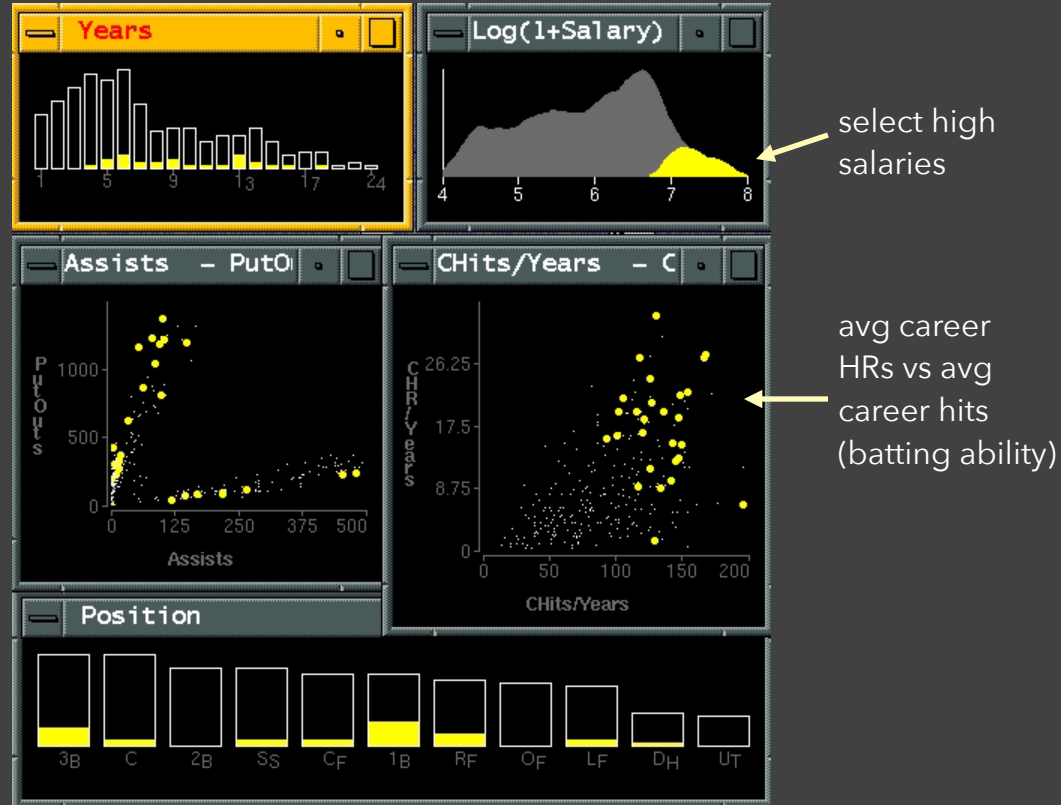
Baseball Statistics [Wills 95]



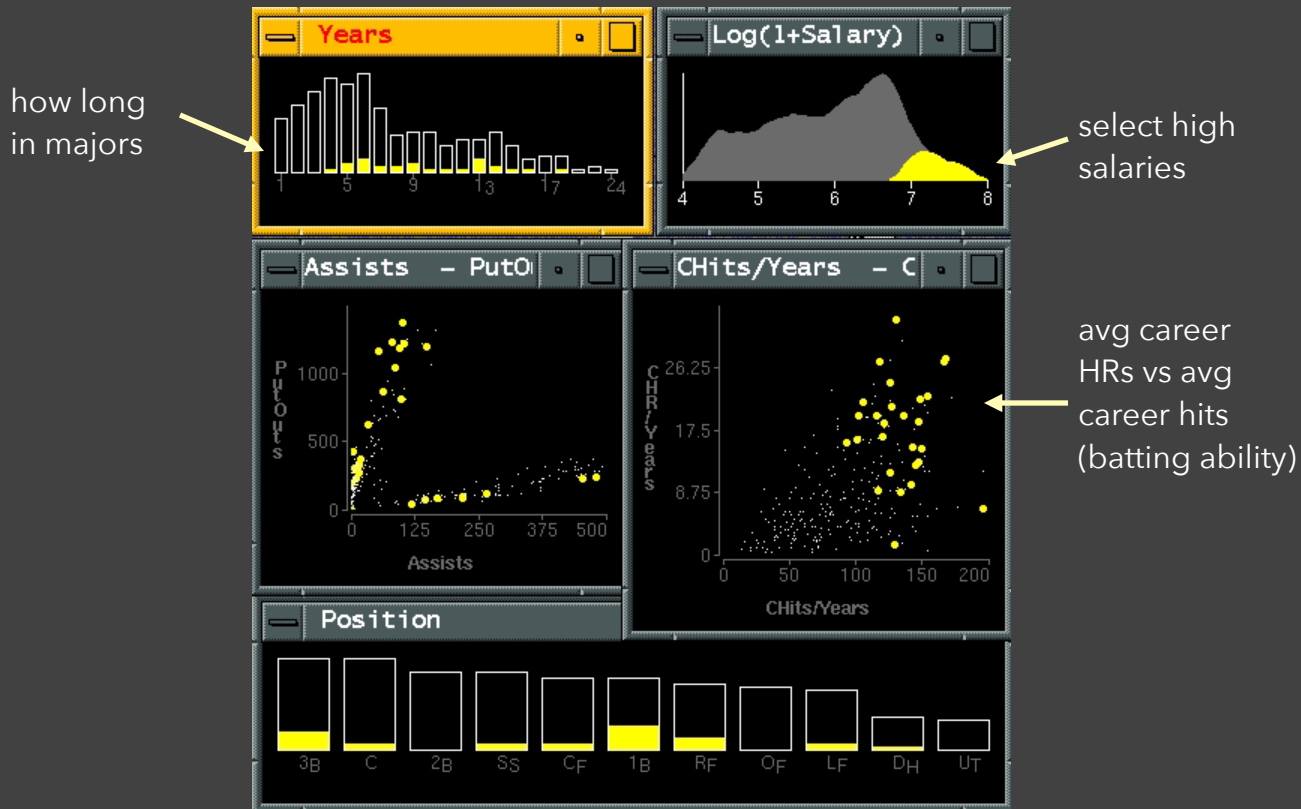
Baseball Statistics [Wills 95]



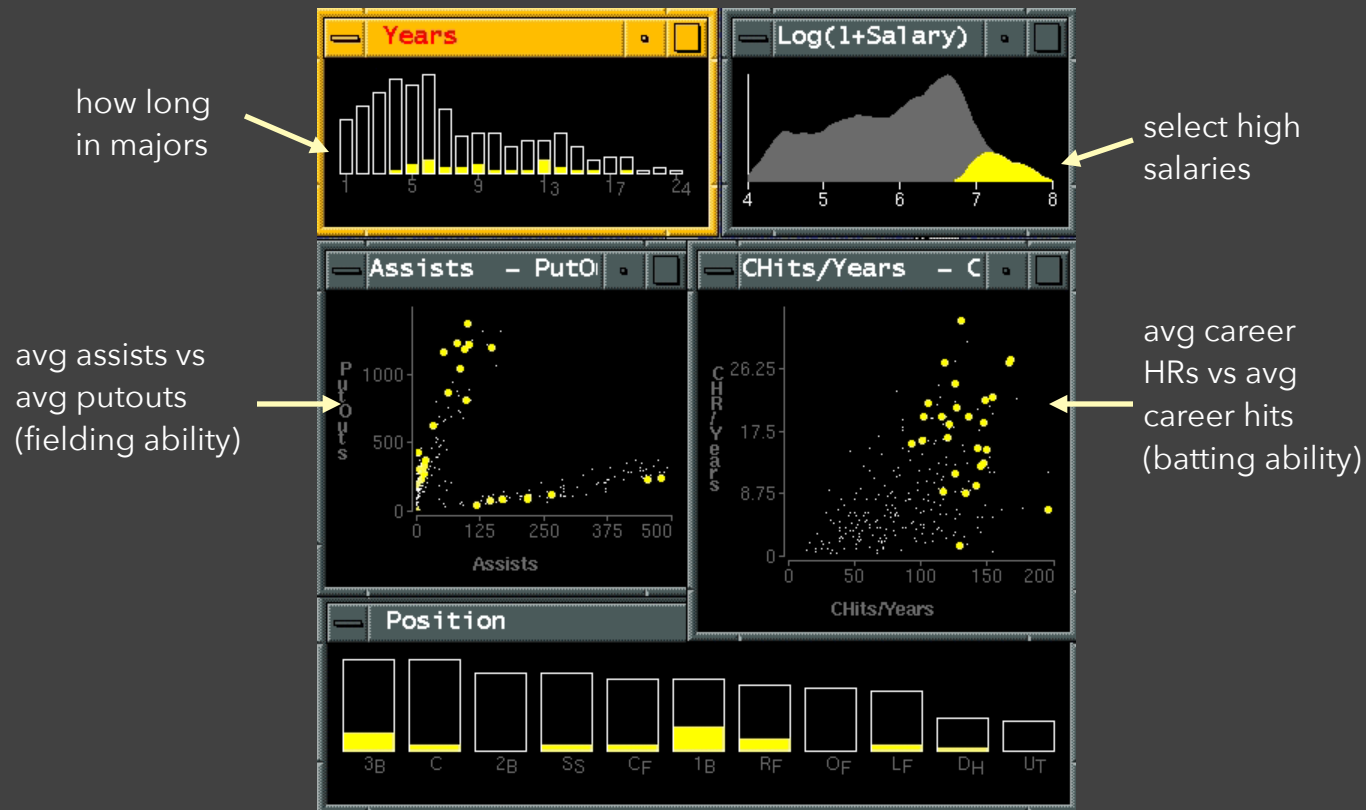
Baseball Statistics [Wills 95]



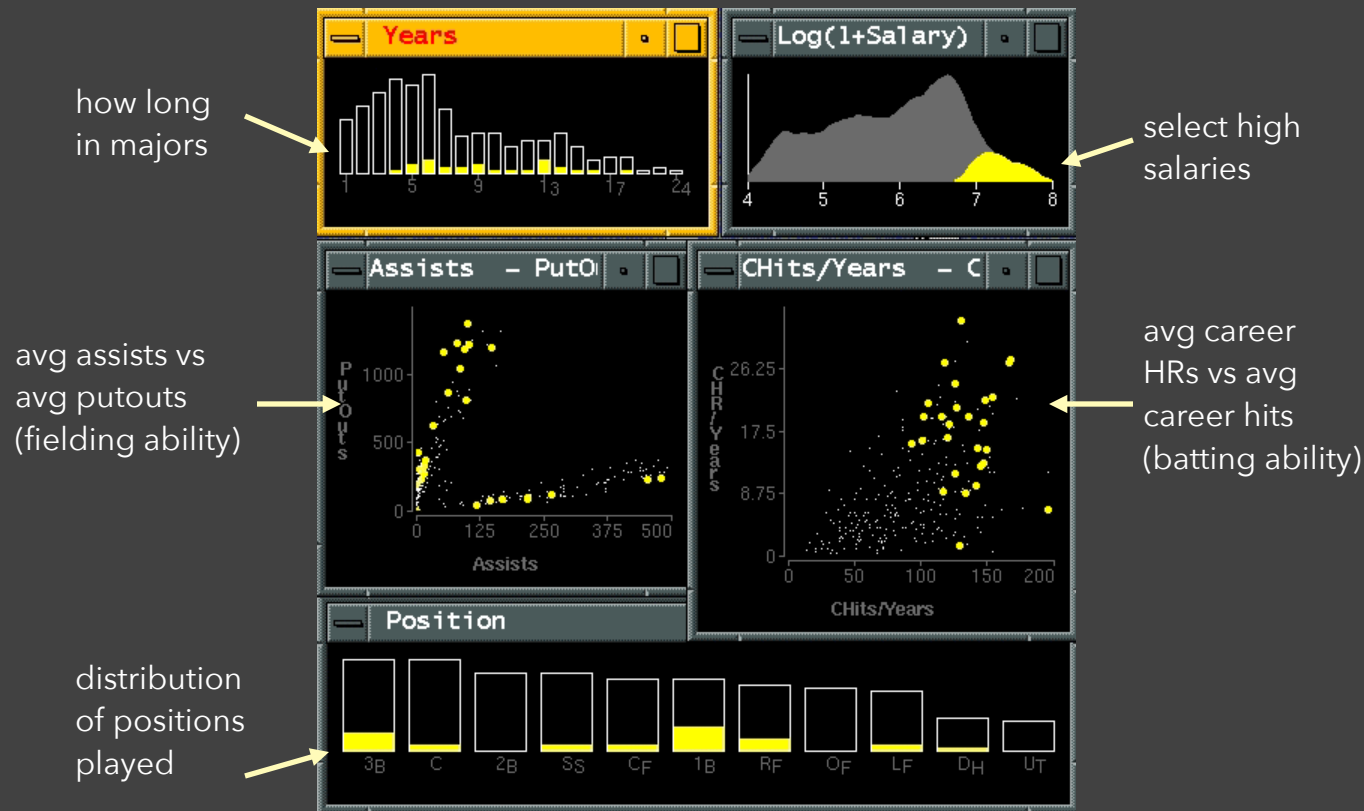
Baseball Statistics [Wills 95]



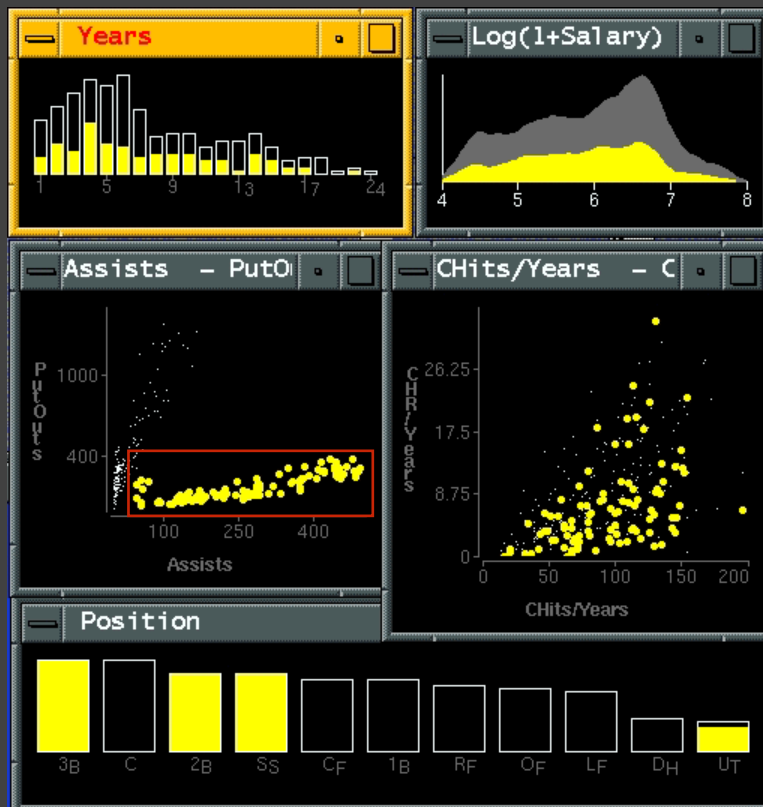
Baseball Statistics [Wills 95]



Baseball Statistics [Wills 95]



Linking Assists to Positions



Dynamic Queries

Query & Results

```
SELECT house FROM seattle_homes  
WHERE price < 1,000,000 AND bedrooms > 2  
ORDER BY price
```

Dynamic Browser : DC Home Finder

IdNumber	Dwelling	Address	City
2	House	5256 S. Capitol St.	Beltsville, MD
4	House	5536 S. Lincoln St.	Beltsville, MD
5	House	5165 Jones Street	Beltsville, MD
8	House	5007 Jones Street	Beltsville, MD
9	House	4872 Jones Street	Beltsville, MD
17	House	5408 S. Capitol St.	Beltsville, MD
20	House	5496 S. Capitol St.	Beltsville, MD
85	Condo	5459 S. Lincoln St.	Laurel, MD
86	Condo	5051 S. Lincoln St.	Laurel, MD
88	Condo	5159 Hamilton Street	Laurel, MD
92	Condo	5132 Hamilton Street	Laurel, MD
93	Condo	5221 S. Lincoln St.	Laurel, MD
94	Condo	5043 S. Lincoln St.	Laurel, MD
95	Condo	4970 Jones Street	Laurel, MD
97	Condo	4677 Jones Street	Laurel, MD
98	Condo	4896 S. Capitol St.	Laurel, MD
99	Condo	5048 S. Capitol St.	Laurel, MD
100	Condo	4597 31st Street	Laurel, MD
101	Condo	5306 S. Lincoln St.	Laurel, MD
103	Condo	5562 Glass Road	Laurel, MD
105	Condo	5546 Hamilton Street	Laurel, MD
152	House	7670 31st Street	Upper Marlboro, MD

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

Design Time

Given housing data with:

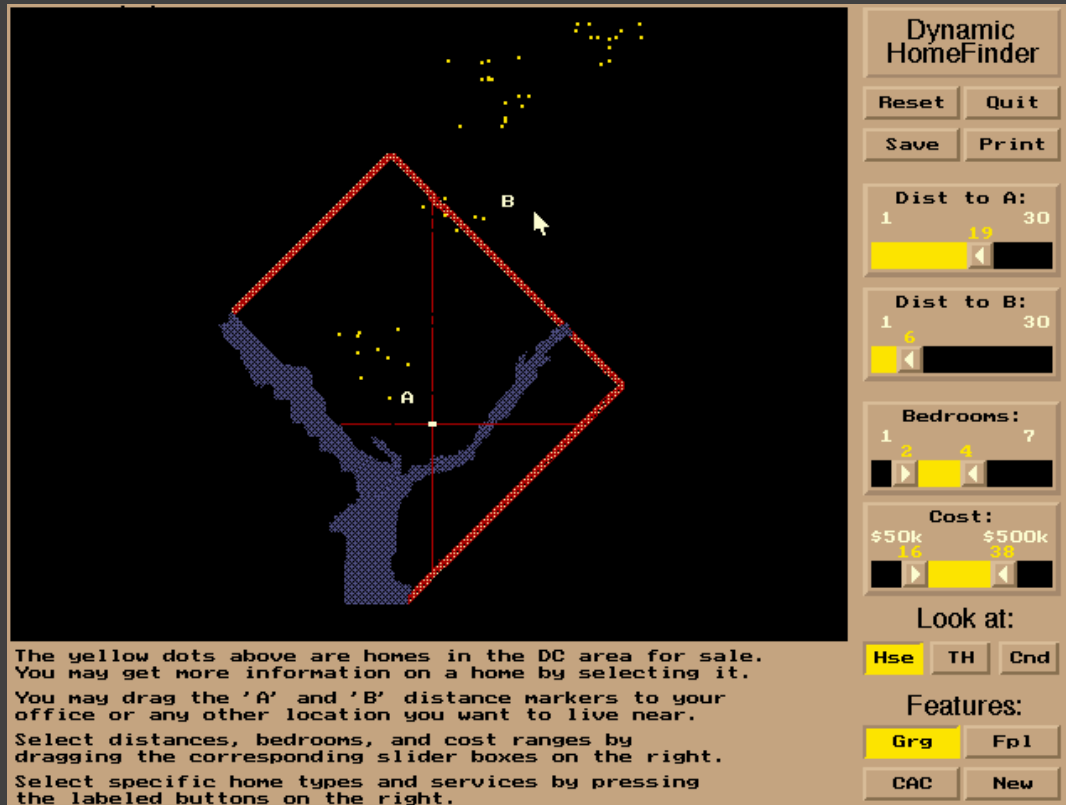
- price
- address
- type (house/condo/...)
- bedroom count
- bathroom count

What forms of interaction might be useful for house hunters? Think about the *task* first, then how to support it.

Dynamic Browser : DC Home Finder

IdNumber	Dwelling	Address	City
2	House	5256 S. Capitol St.	Beltsville, MD
4	House	5536 S. Lincoln St.	Beltsville, MD
5	House	5165 Jones Street	Beltsville, MD
8	House	5007 Jones Street	Beltsville, MD
9	House	4872 Jones Street	Beltsville, MD
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20	House	5496 S. Capitol St.	Beltsville, MD
85	Condo	5459 S. Lincoln St.	Laurel, MD
86	Condo	5051 S. Lincoln St.	Laurel, MD
88	Condo	5159 Hamilton Street	Laurel, MD
92	Condo	5132 Hamilton Street	Laurel, MD
93	Condo	5221 S. Lincoln St.	Laurel, MD
94	Condo	5043 S. Lincoln St.	Laurel, MD
95	Condo	4970 Jones Street	Laurel, MD
97	Condo	4677 Jones Street	Laurel, MD
98	Condo	4896 S. Capitol St.	Laurel, MD
99	Condo	5048 S. Capitol St.	Laurel, MD
100	Condo	4597 31st Street	Laurel, MD
101	Condo	5306 S. Lincoln St.	Laurel, MD
103	Condo	5562 Glass Road	Laurel, MD
105	Condo	5546 Hamilton Street	Laurel, MD
152	House	7670 31st Street	Upper Marlboro, MD

HomeFinder

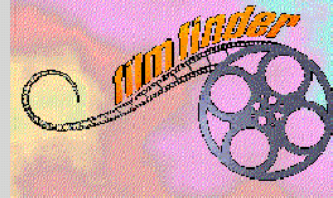
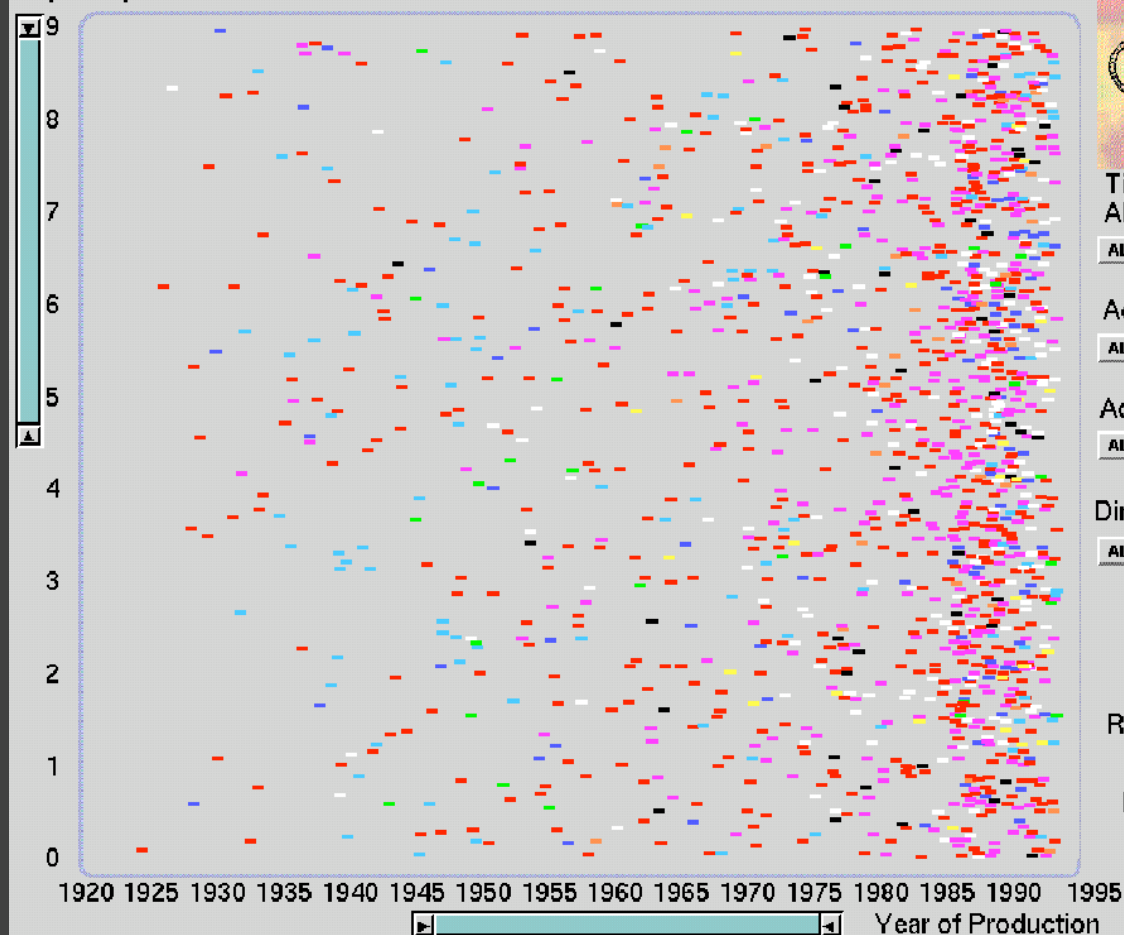


[Williamson and Shneiderman 92]

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

Popularity



Title :

ALL

ALL

A B C D F G H L M N P R S T W Z

Actor : ALL

ALL

A B C D F G H J K L M P R S T W Z

Actress : ALL

ALL

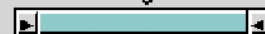
A B C D F G H K L M P R S T W Z

Director : ALL

ALL

A B C D F G H J K L M P R S T W Z

0 Length 450



0 450

Ratings ☐ G ☐ PG

☐ PG-13 ☐ R

Films Shown: 1455



Copyright (C) 1993 HCIL

ALL

Drama

Mystery

Comedy

Music

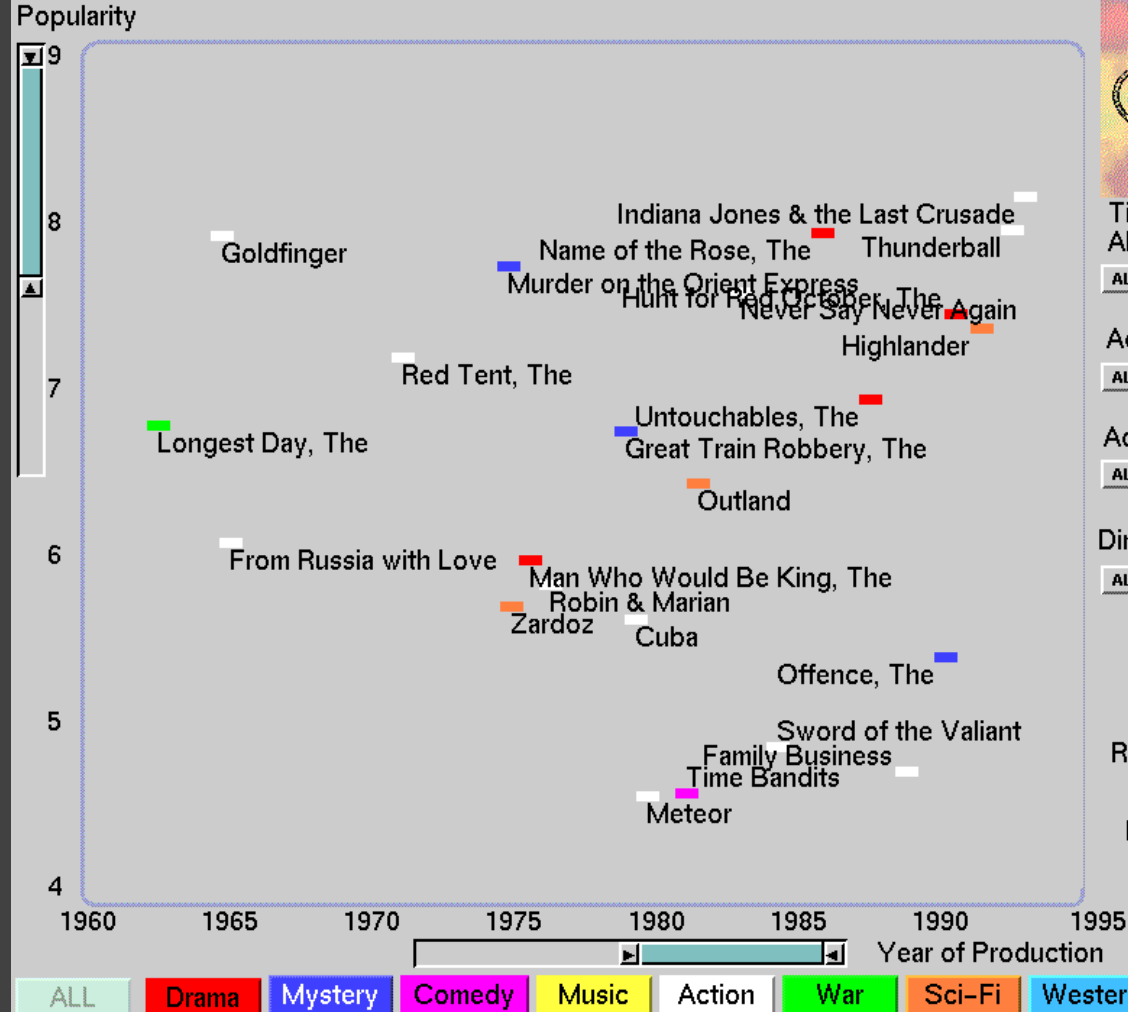
Action

War

Sci-Fi

Western

Horror



Title :

ALL

ALL

A B C D F G H L M N P R S T W Z

Actor : Connery, Sean

ALL

A B C D F G H J K L M P R S T W Z

Actress : ALL

ALL

A B C D F G H K L M P R S T W Z

Director : ALL

ALL

A B C D F G H J K L M P R S T W Z

60 Length 269

0 450

Ratings

G

PG

PG-13

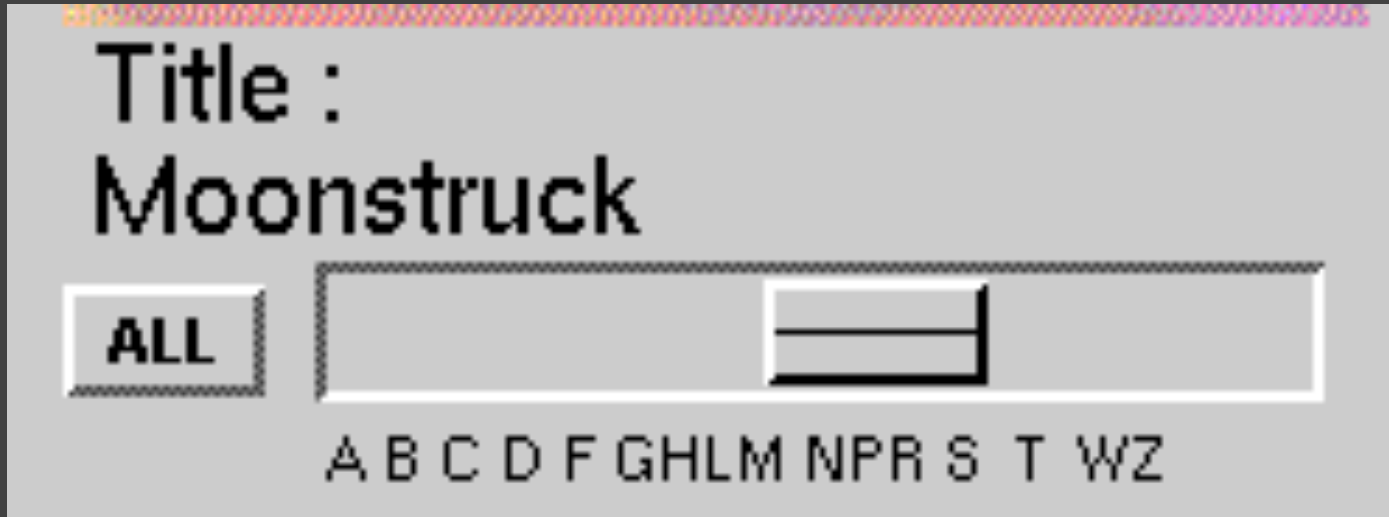
R

Films Shown: 24



Copyright (C) 1993 HCIL

Alphaslider (?)



Popularity



Details-on-Demand

9
8
7
6
5
4
3
2

Witches of Eastwick, The

Director: **Miller, George** Year: 1987

Country: USA

Language: English

Actors:

Actresses:

Nicholson, Jack
Jenkins, Richard
Joakum, Keith
Struycker, Carel

Cher
Sarandon, Susan
Pfeiffer, Michelle
Cartwright, Veron



1960 1965 1970 1975 1980 1985 1990 1995



Year of Production

ALL

Drama

Mystery

Comedy

Music

Action

War

Sci-Fi

Western

Horror



Title :

ALL

ALL

AB C D F G H L M N P R S T W Z

Actor : ALL

ALL

AB C D F G H J K L M P R S T W Z

Actress : Pfeiffer, Michelle

ALL

AB C D F G H K L M P R S T W Z

Director : Miller, George

ALL

AB C D F G H J K L M P R S T W Z

105

Length

231



0

450

Ratings

G

PG

PG-13

R

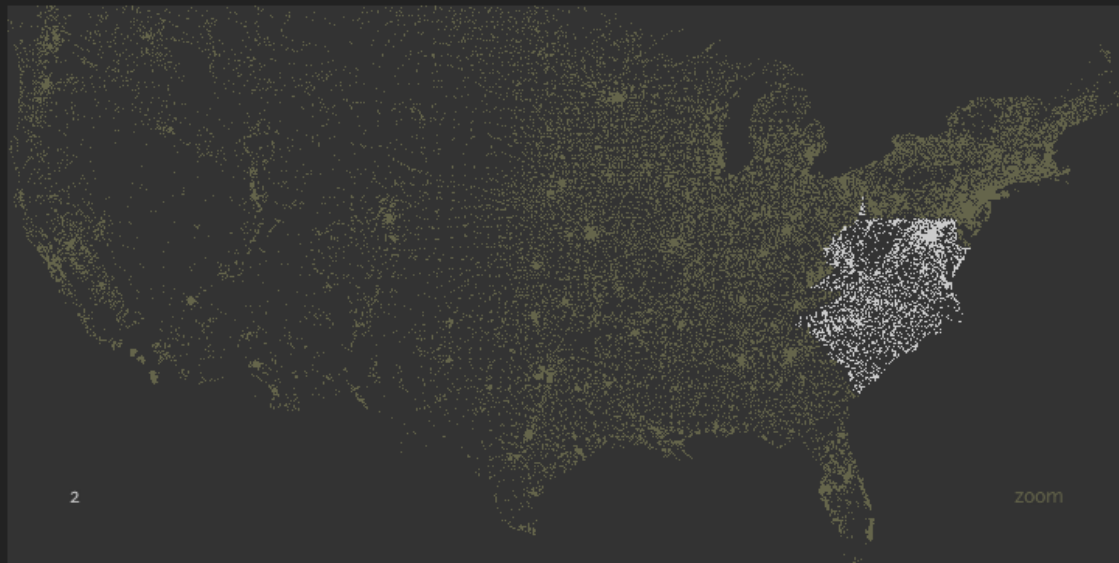
Films Shown: 210



Copyright (C) 1993 HCIL

- The Attribute Explorer

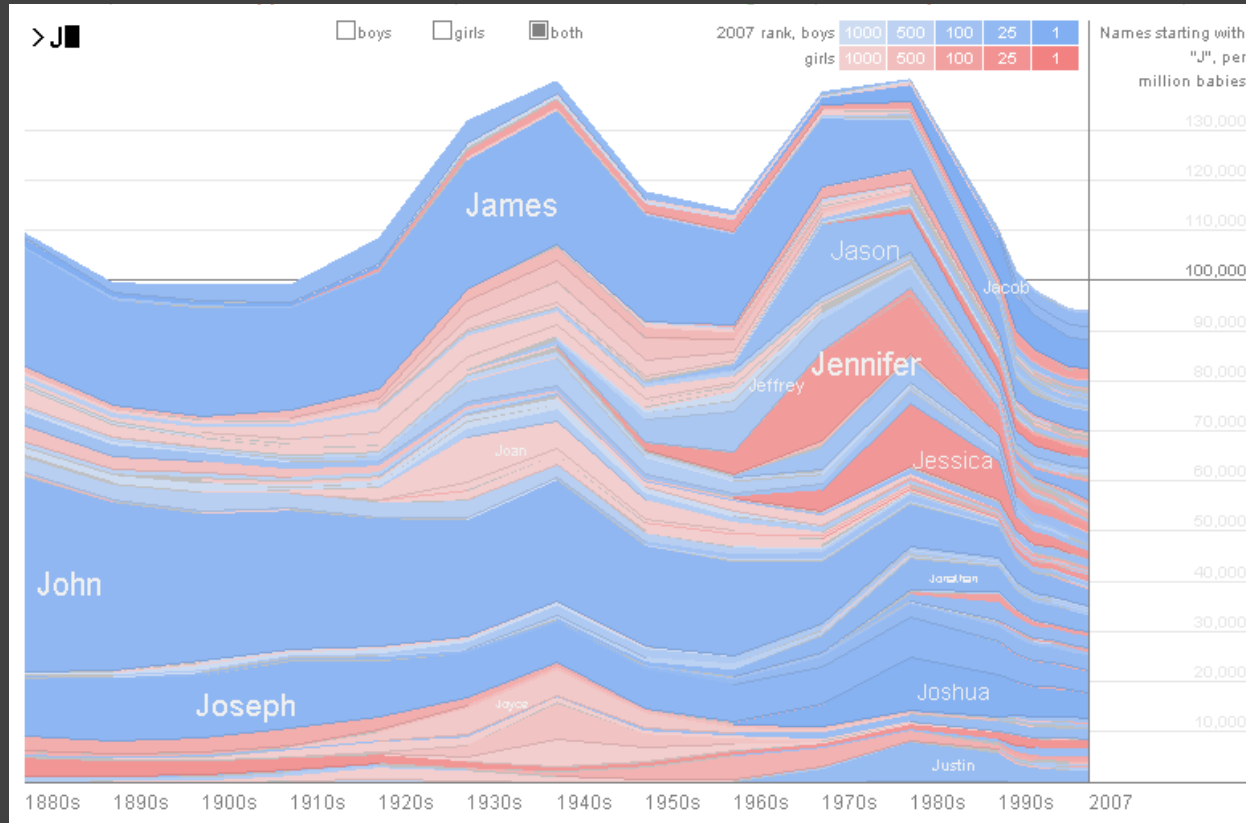
Zipdecode [Fry 04]



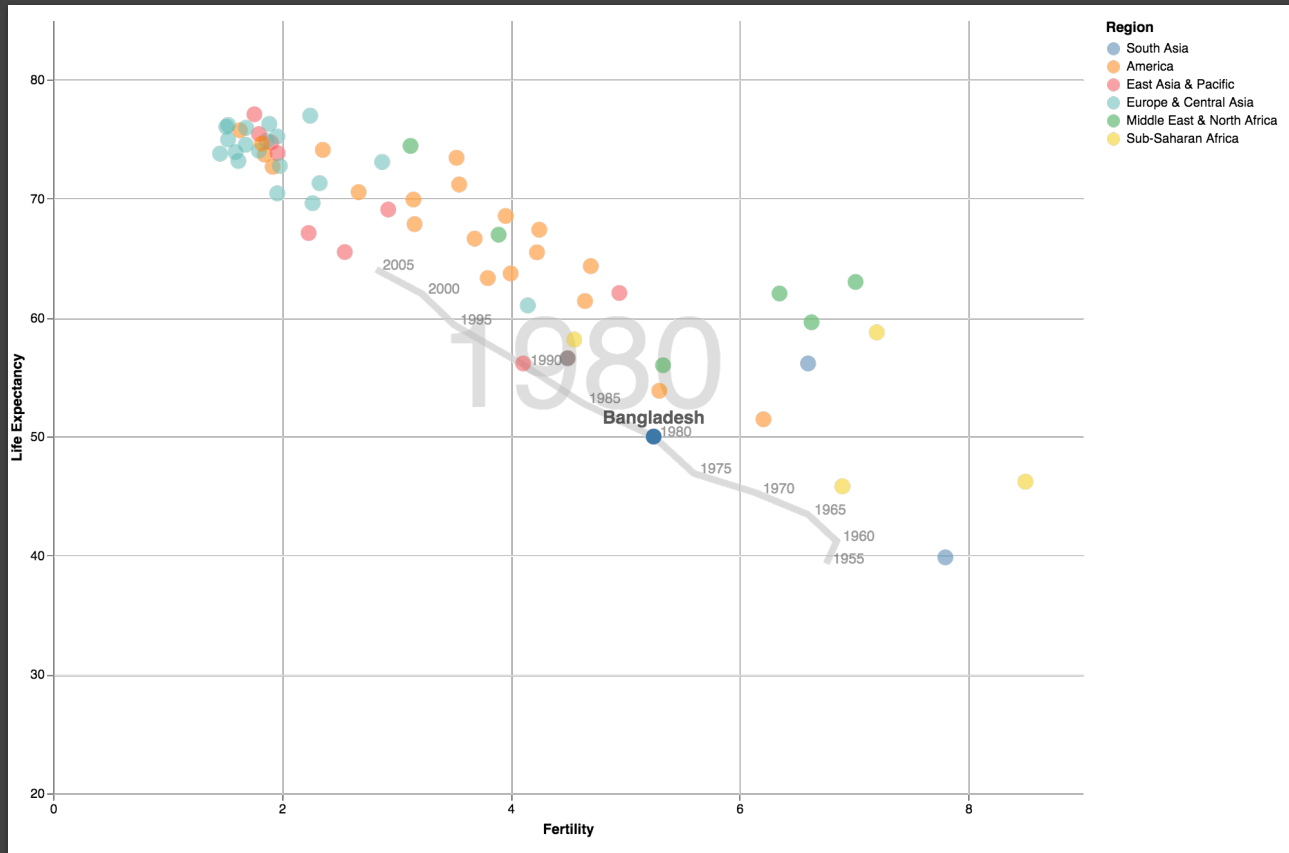
Hit the letter **z**, or click the word **zoom** to enable or disable zooming.

Hold down **shift** while typing a number to replace the previous number (U.S. keyboards only).

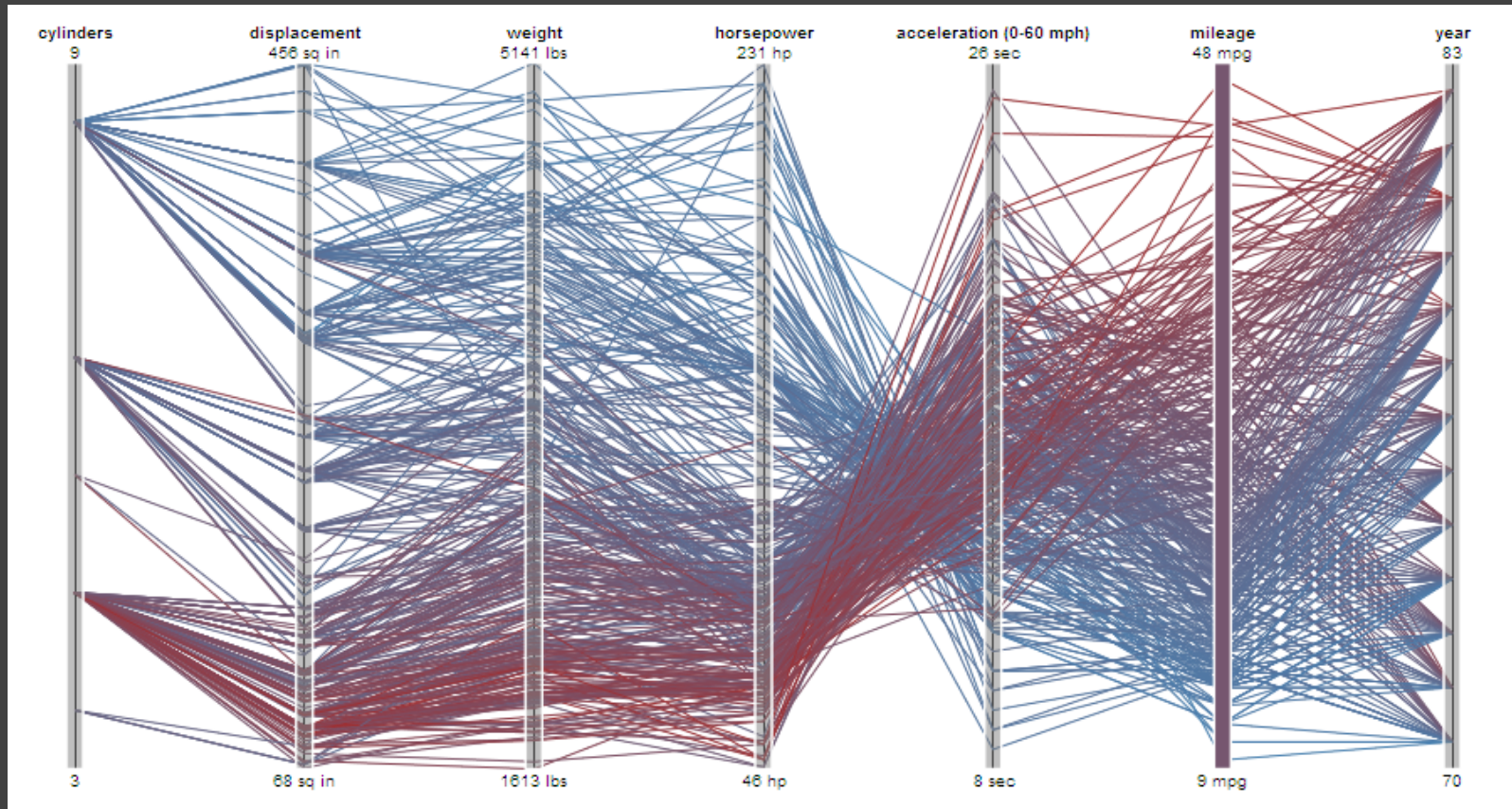
NameVoyager [Wattenberg 06]



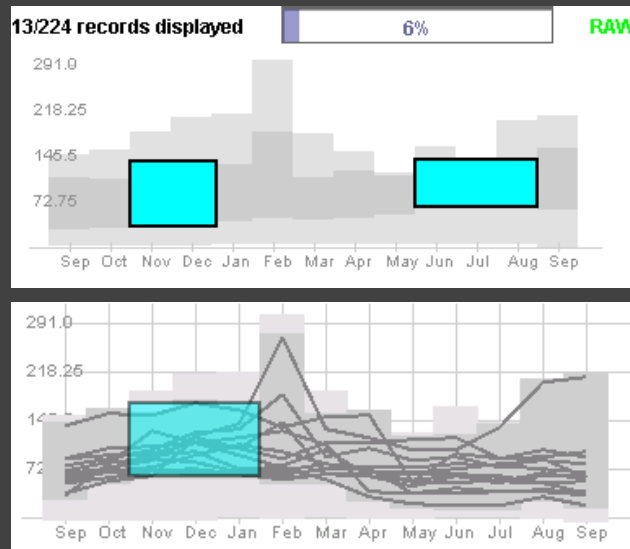
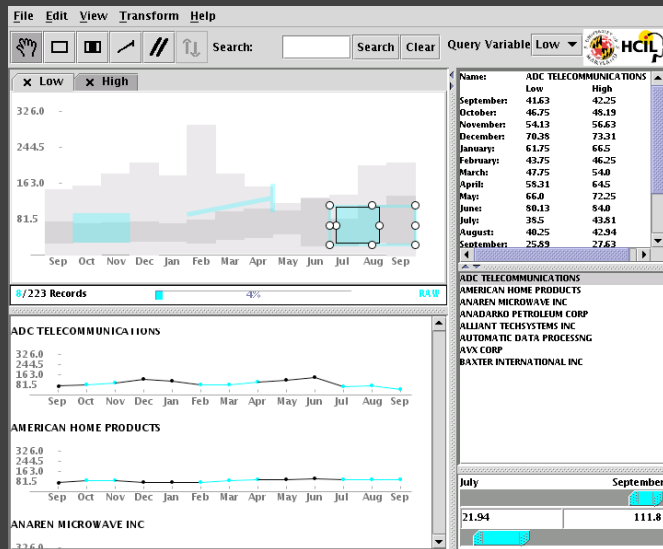
DimpVis [Kondo 14]



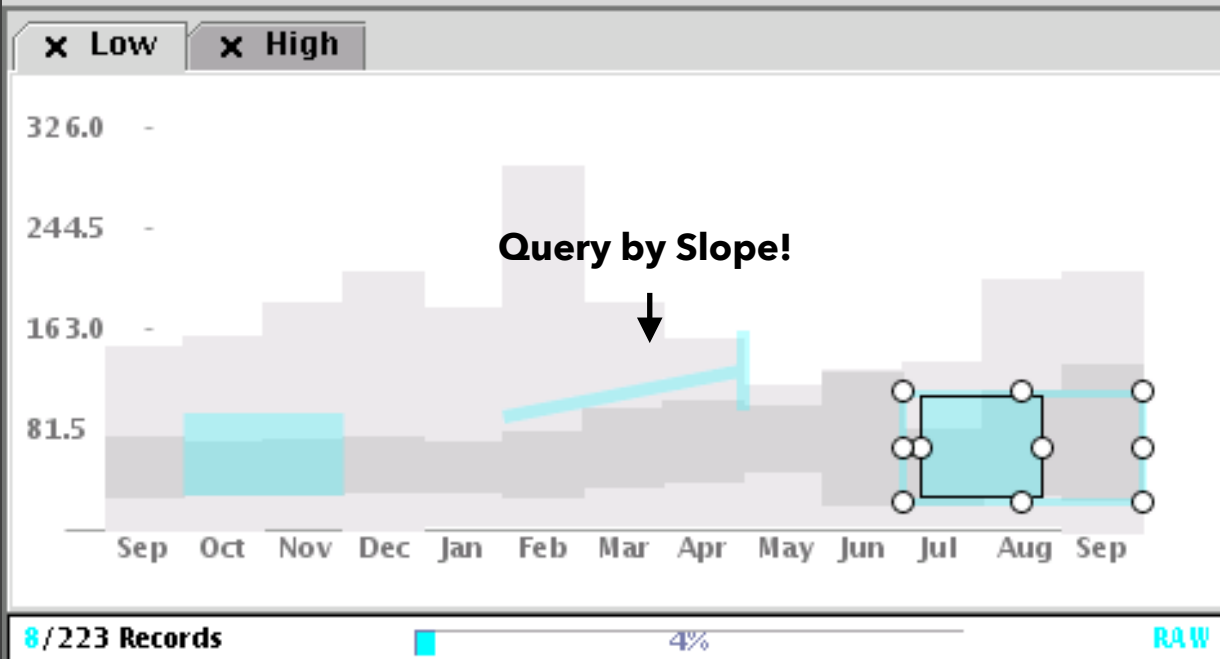
Parallel Coordinates [Inselberg]



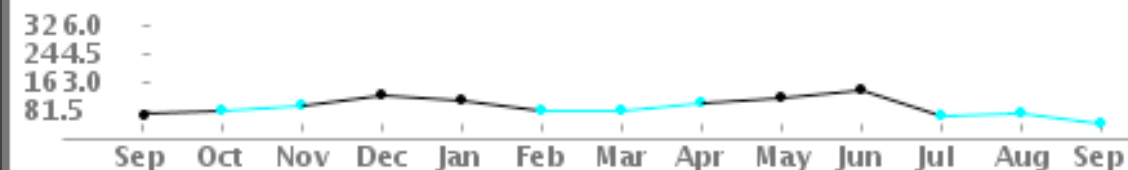
TimeSearcher [Hocheiser 02]



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



ADC TELECOMMUNICATIONS



AMERICAN HOME PRODUCTS

326.0

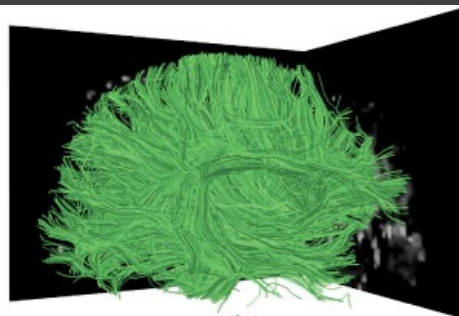
Name:	ADC TELECOMMUNIC	
	Low	High
September:	41.63	42.2
October:	46.75	48.1
November:	54.13	56.6
December:	70.38	73.3
January:	61.75	66.5
February:	43.75	46.2
March:	47.75	54.0
April:	58.31	64.5
May:	66.0	72.2
June:	80.13	84.0
July:	38.5	43.8
August:	40.25	42.9
September:	25.89	27.6

ADC TELECOMMUNICATIONS
 AMERICAN HOME PRODUCTS
 ANAREN MICROWAVE INC
 ANADARKO PETROLEUM CORP
 ALLIANT TECHSYSTEMS INC
 AUTOMATIC DATA PROCESSNG
 AVX CORP
 BAXTER INTERNATIONAL INC

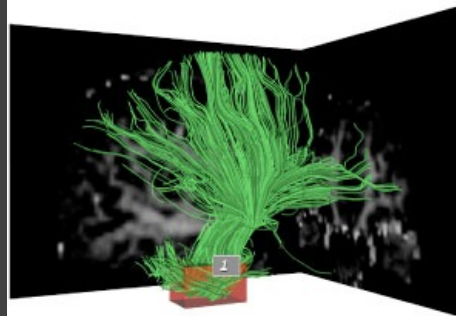
3D Dynamic Queries [Akers 04]



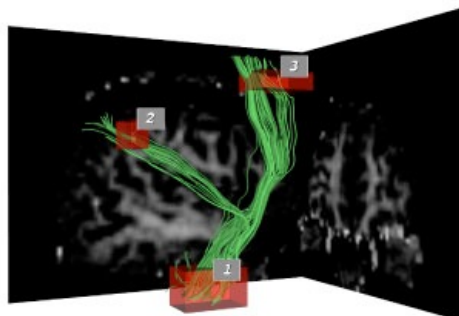
(a)



(b)

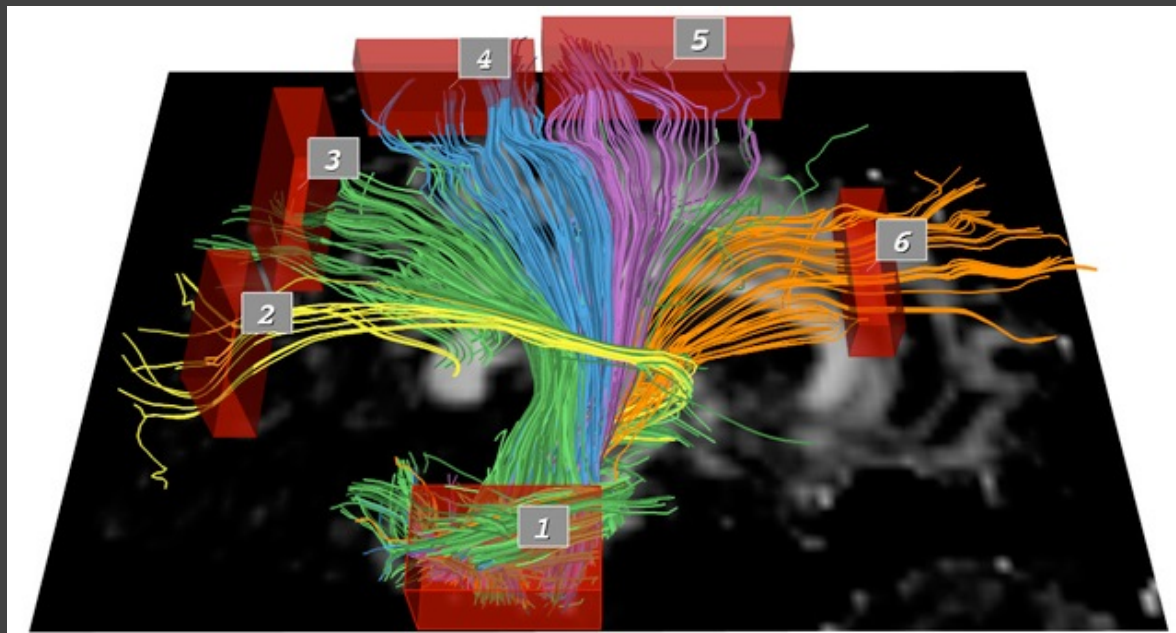


(c)



(d)

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

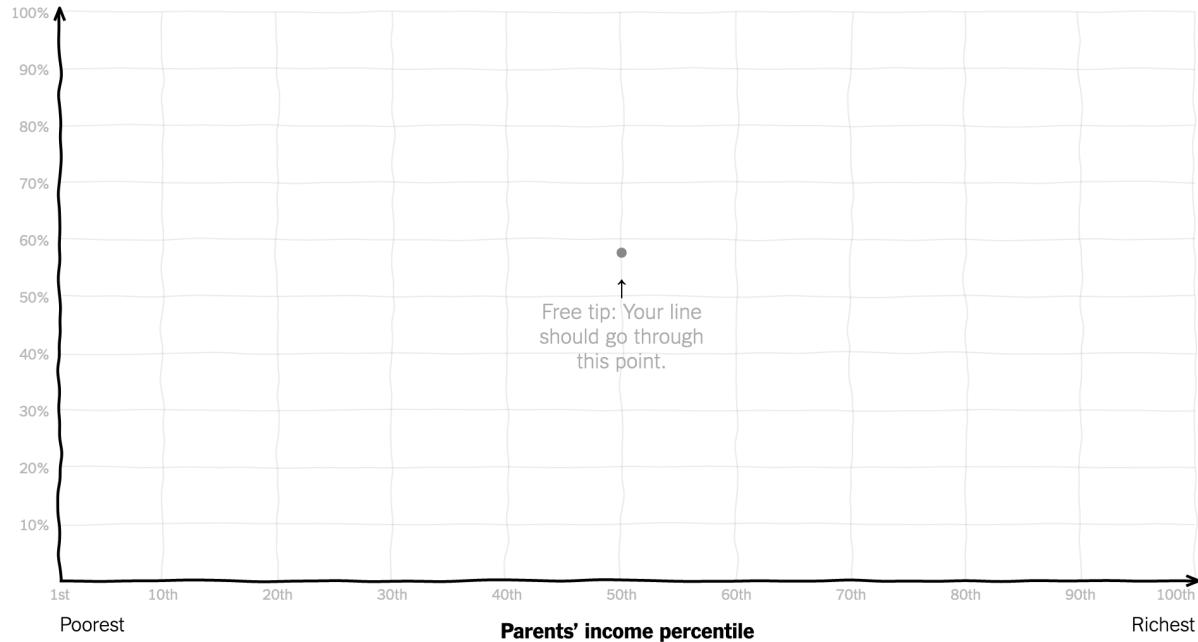
Who would use these kinds of tools?

Prompting Reflection

You Draw It [Aisch et al. '15]

Draw your line on the chart below

Percent of children who attended college



Interaction 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

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 10/15 EOD**.

A2: Peer Reviews

You will be assigned two peer W2 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 to a A2 Peer Review thread on Ed, along with a link to a Google Form. You should submit two forms: one for each A2 peer review.

Due by **Tue 10/21 EOD.**

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?

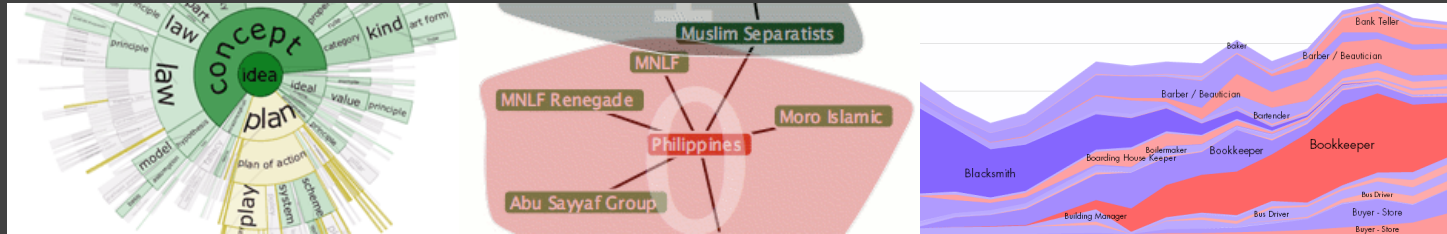
Suggest alternative design directions, or even wacky half-baked ideas.

Example: "What if we got rid of the slider and enabled direct manipulation navigation by dragging data points directly?"

A3: Interactive Visualization

Create an interactive visualization in a team of 1-3 people. Choose a dataset and a driving question, develop a visualization + interaction techniques, then deploy your visualization on the web.

1. Form team, topic & data and start prototyping.
2. Complete implementation and submit to Gradescope by *EOD* on **Monday, Nov 3**.



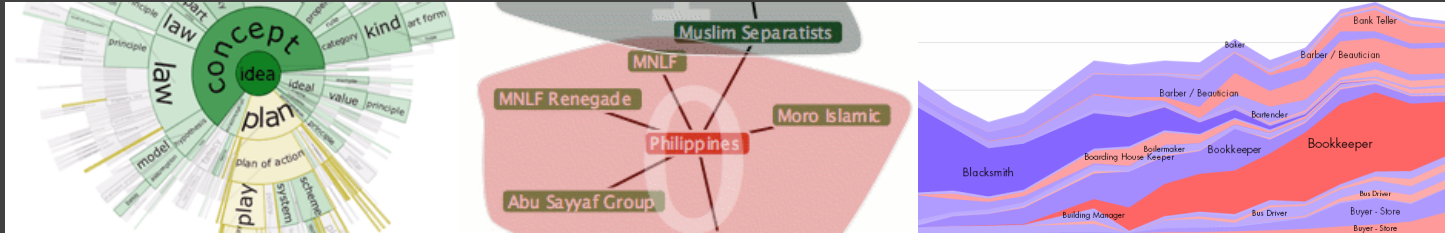
Form a Project Team

Form a **team of 1-3 people** for the A3 assignment.

Submit team composition using provided form.

If you're looking for team mates, you can post on Ed about your interests/skills/project ideas!

You may continue with the same team for the final project, or form a new team later. It's up to you.

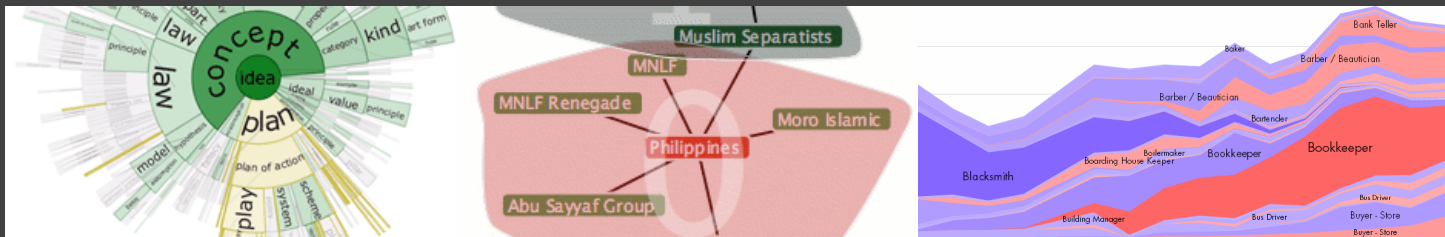


Requirements

Interactive. You must implement interaction methods! However, this is not only selection / filtering / tooltips. Also consider annotations or other narrative features to draw attention and provide additional context

Web-based. D3/Vega-Lite are encouraged, but not required. Deploy to web using GitLab pages.

Write-up. Provide design rationale.

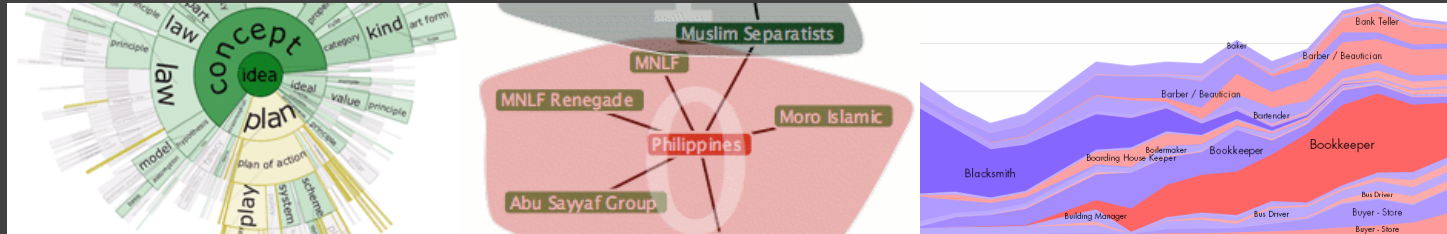


Interactive Prototype Tips

Start now. It will take longer than you think.

Keep it simple. Choose a *minimal* set of interactions that enables users to explore and generate interesting insights. Do not feel obligated to convey *everything* about the data: focus on a compelling subset.

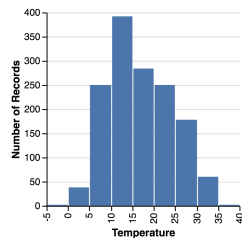
Promote engagement. How do your chosen interactions reveal interesting observations?



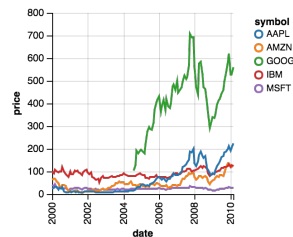
An Interaction Grammar (Vega-Lite Selections)

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

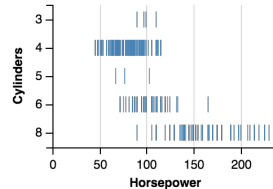
Histogram



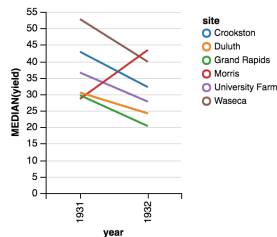
Line Chart



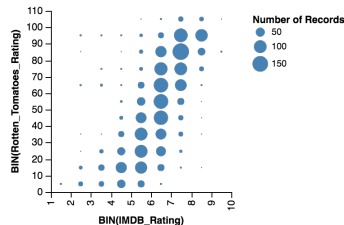
Strip Plot



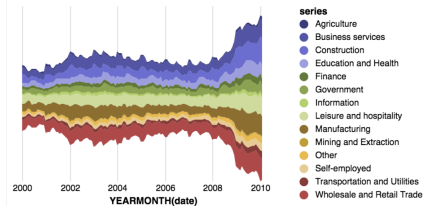
Slope Graph



Binned Scatter Plot

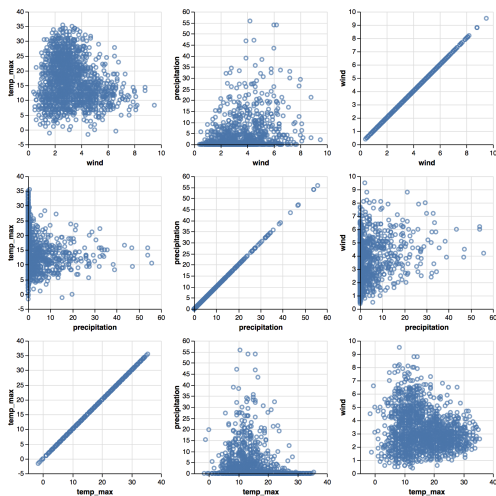


Area Chart

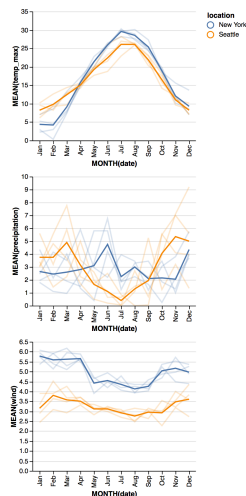


Vega-Lite: A Grammar of Graphics

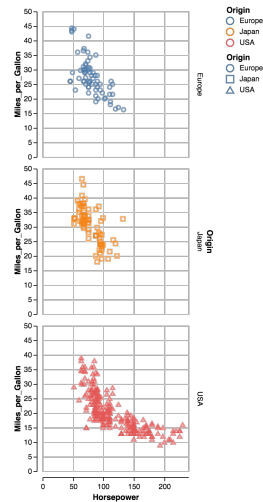
Scatter Plot Matrix



Concat & Layered Views

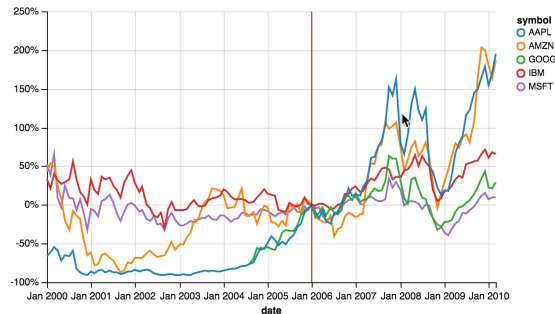


Faceted Views

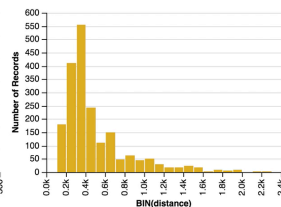
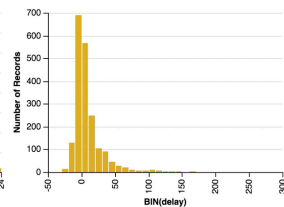
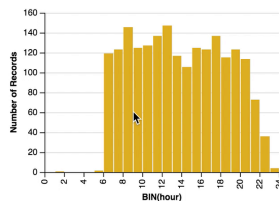
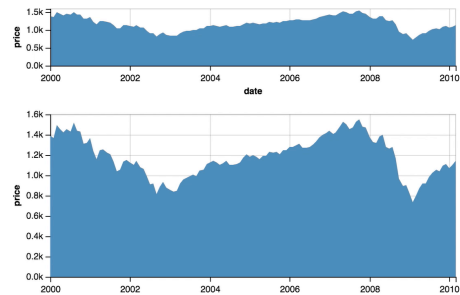


Vega-Lite: A Grammar of Multi-View Graphics

Indexed Chart



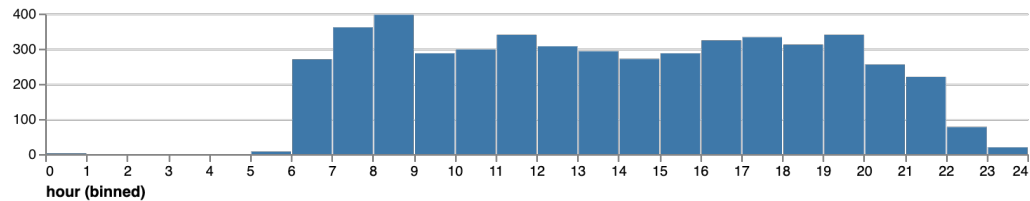
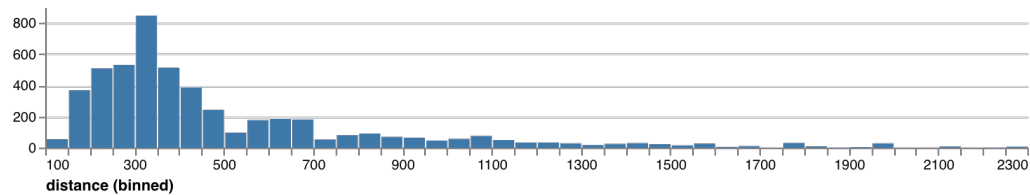
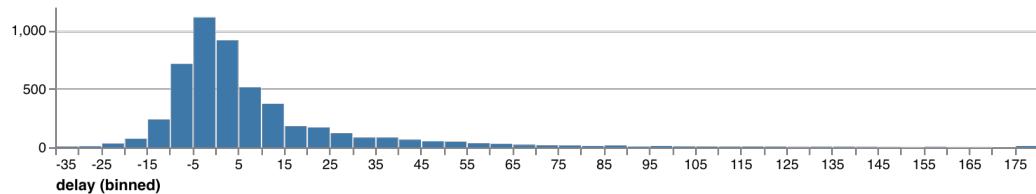
Focus + Context



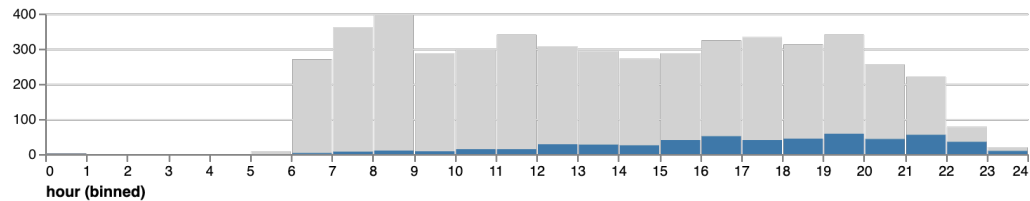
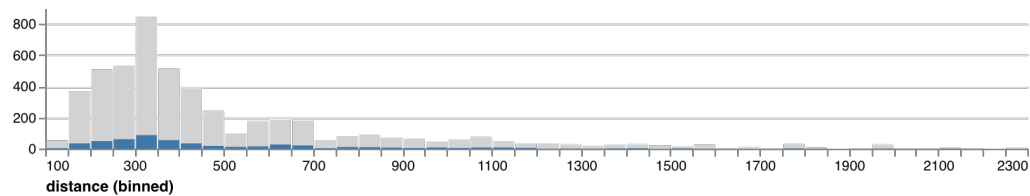
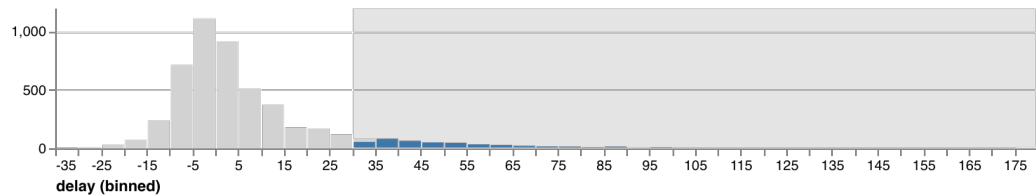
Cross-Filtering

Vega-Lite: A Grammar of **Interactive** Graphics

Cross-Filtering in Vega-Lite

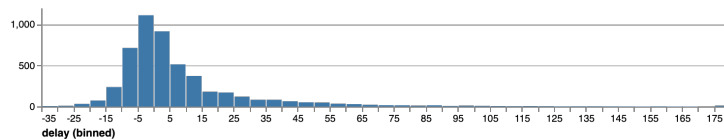


Cross-Filtering in Vega-Lite



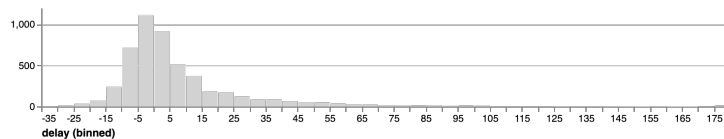
Cross-Filtering in Vega-Lite

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



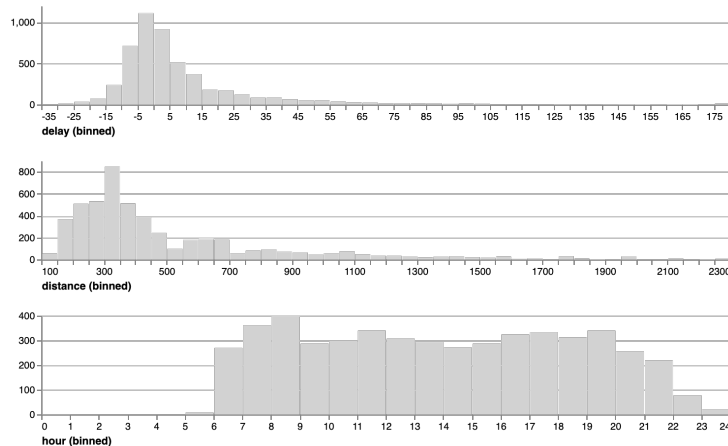
Cross-Filtering in Vega-Lite

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



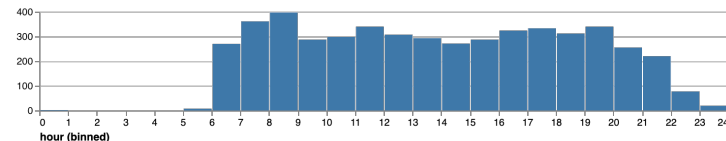
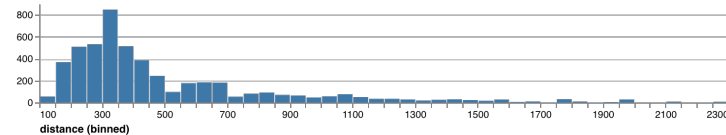
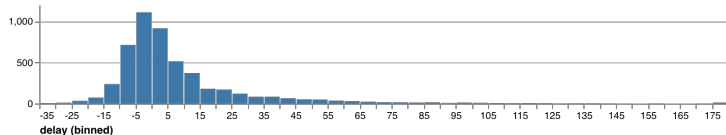
Cross-Filtering in Vega-Lite

```
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

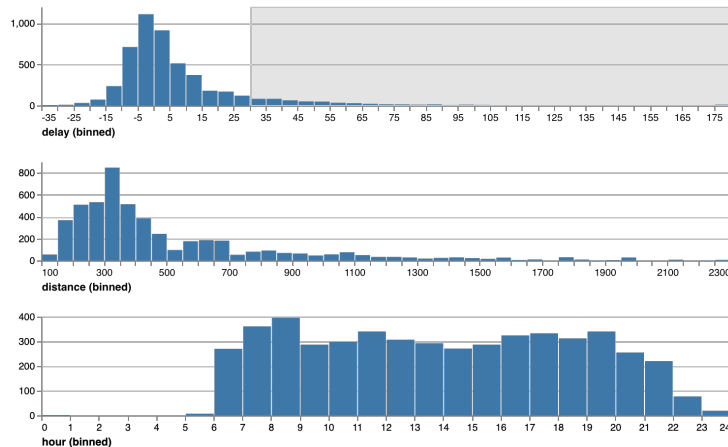
```
layer(  
  markBar().encode(  
    x().fieldQ(repeat('row')).bin(true),  
    y().count(),  
    color().value('lightgrey')  
  ),  
  markBar().encode(  
    x().fieldQ(repeat('row')).bin(true),  
    y().count()  
  )  
).repeat({  
  row: ['delay', 'distance', 'hour']  
})  
.data('data/flights.json')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



Cross-Filtering in Vega-Lite

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

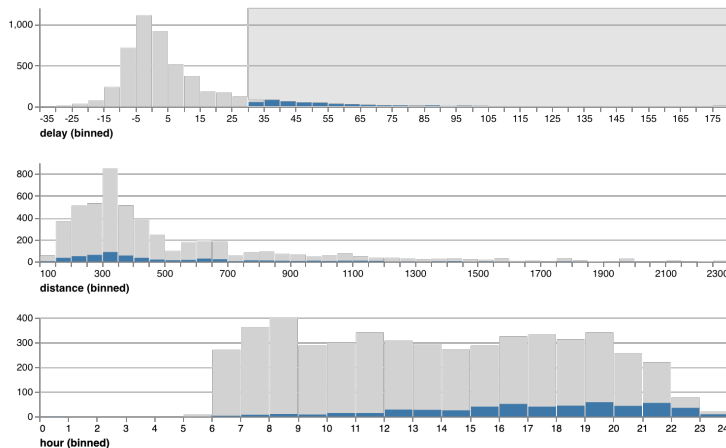
```
layer(  
  markBar().encode(  
    x().fieldQ(repeat('row')).bin(true),  
    y().count(),  
    color().value('lightgrey')  
  ).params(brush),  
  markBar().encode(  
    x().fieldQ(repeat('row')).bin(true),  
    y().count()  
  )  
)  
.repeat({  
  row: ['delay', 'distance', 'hour']  
})  
.data('data/flights.json')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



Cross-Filtering in Vega-Lite

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

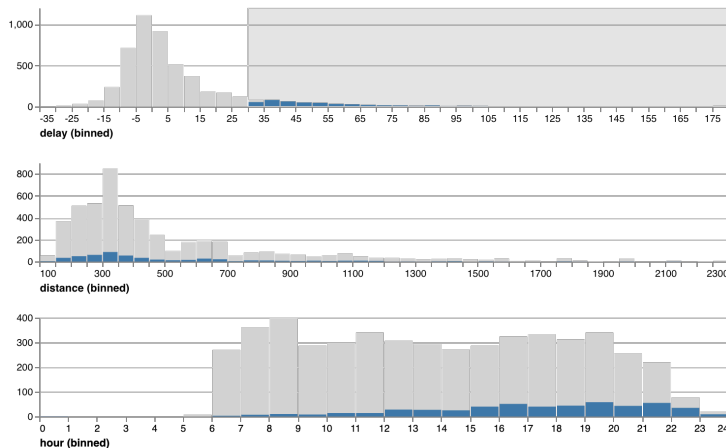
```
layer(  
  markBar().encode(  
    x().fieldQ(repeat('row')).bin(true),  
    y().count(),  
    color().value('lightgrey')  
  ).params(brush),  
  markBar().encode(  
    x().fieldQ(repeat('row')).bin(true),  
    y().count()  
  ).transform(filter(brush))  
)  
.repeat({  
  row: ['delay', 'distance',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

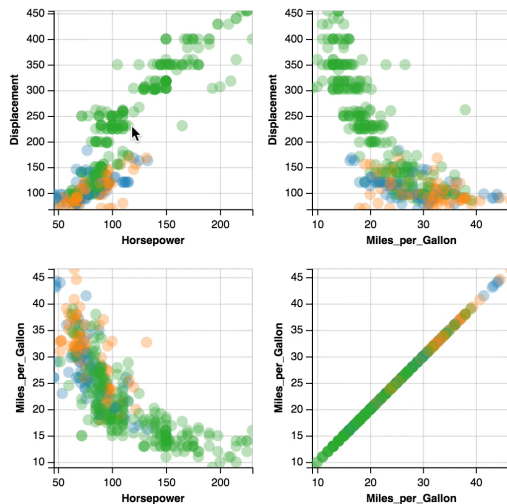
Scale inversion: visual space → data space

Predicate: test if a data record is selected

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

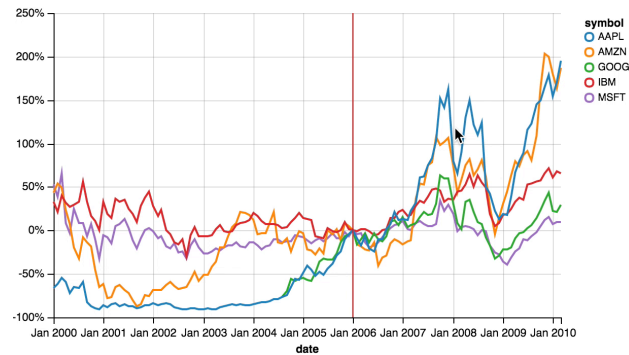
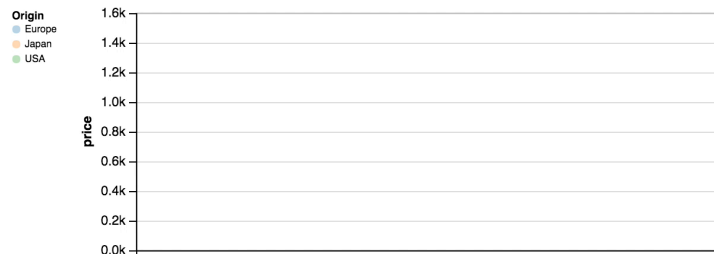
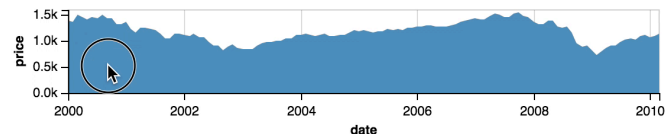
Selections

Selections *invert* scales and
parameterize graphics



Bind selection to scale domains:
Synchronized Pan & Zoom!

Overview + Detail



Parameterized Transformations