

# CSE 442 - Data Visualization

# Interaction



Jeffrey Heer University of Washington

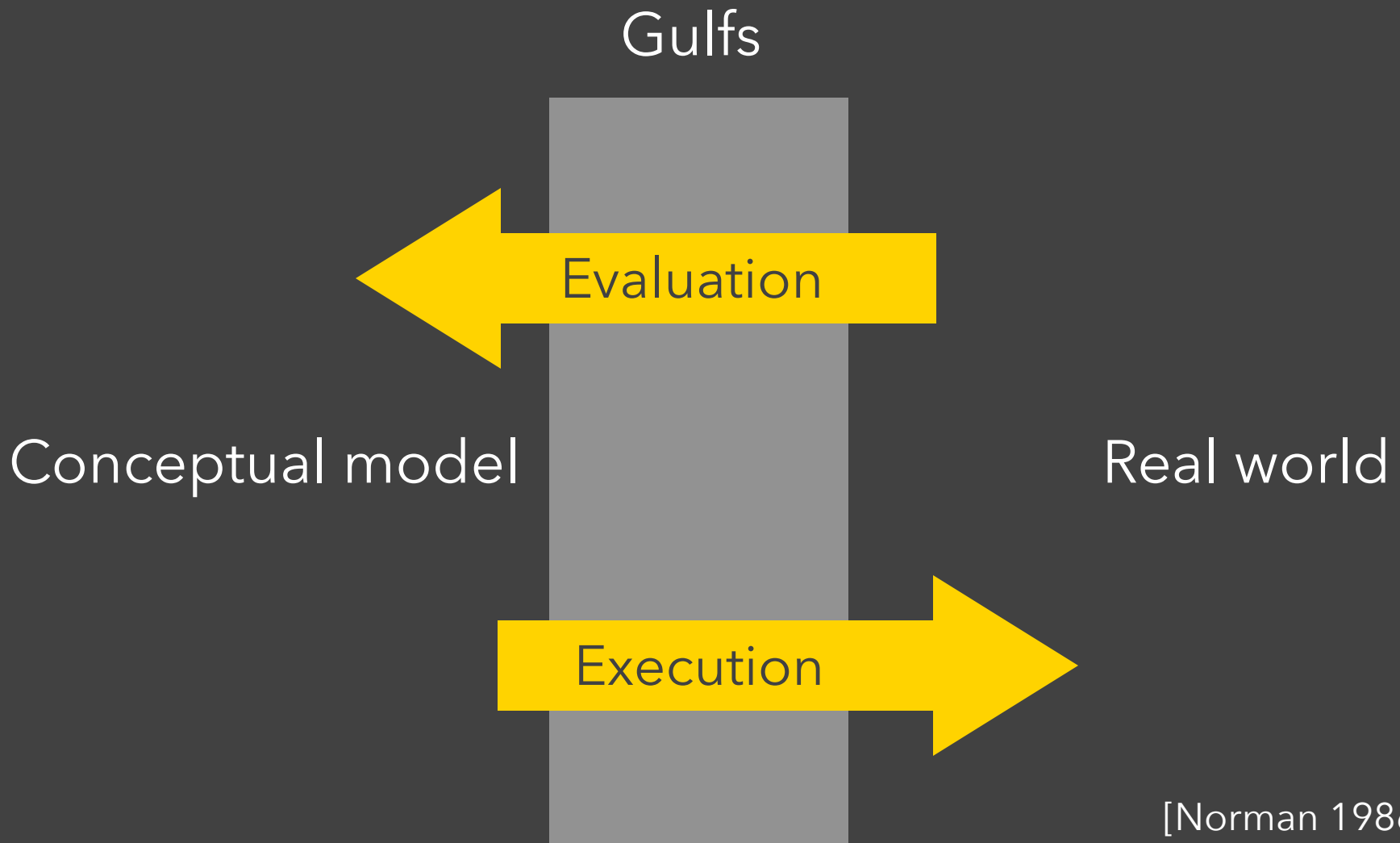
[There is an] apparent challenge that computational artifacts pose to the longstanding distinction between the physical and the social, in the special sense of those things that one designs, builds, and uses, on the one hand, and those things with which one communicates, on the other.

“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



[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:  
 $x, y$  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

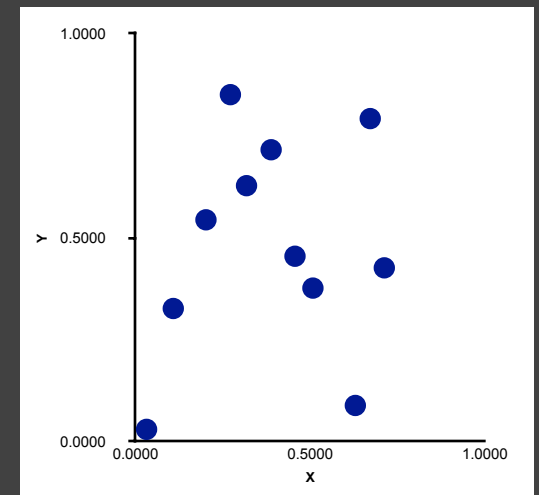
# Gulf of Evaluation

Gulf



Conceptual model:  
 $x, y$  related?

Real world:





# Gulf of Evaluation

Gulf



Conceptual model:  
x, y correlated?

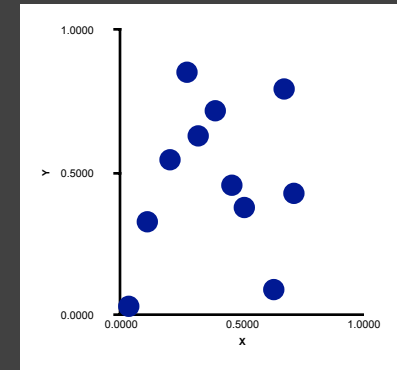
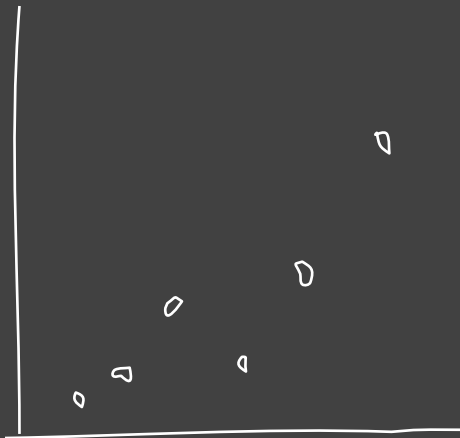
Real world:

$$\rho = -.29$$

# Gulf of Execution

Gulf

Conceptual model:  
Draw a scatterplot



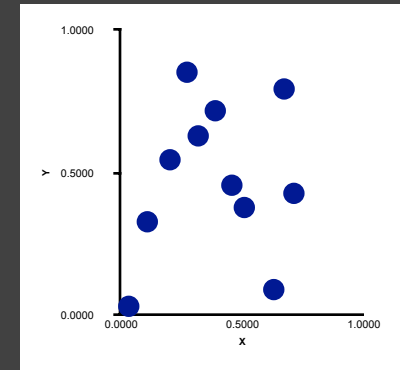
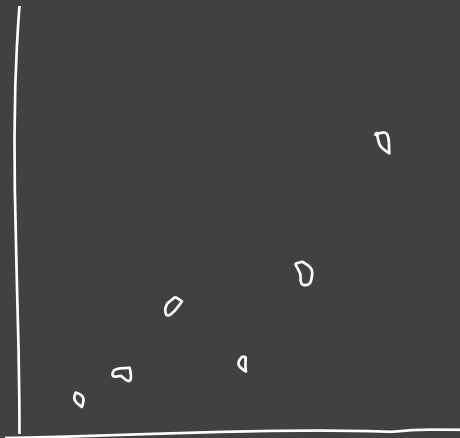
Real world

Move 90 30  
Rotate 35  
Pen down  
...

# Gulf of Execution

Gulf

Conceptual model:  
Draw a scatterplot



Real world

```
v1.markCircle()  
  .encode(  
    v1.x().fieldQ(...),  
    v1.y().fieldQ(...)  
  )
```

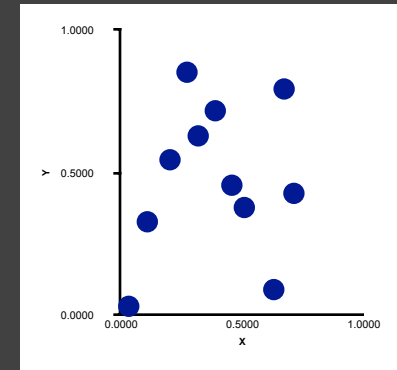
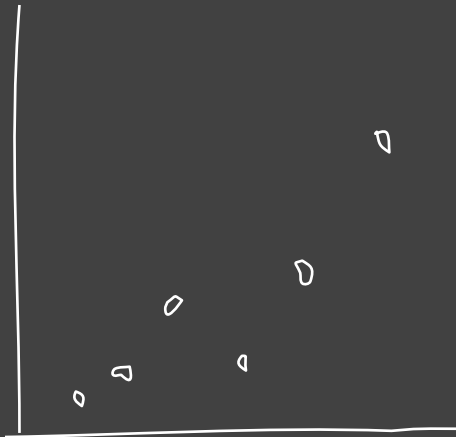
Execution



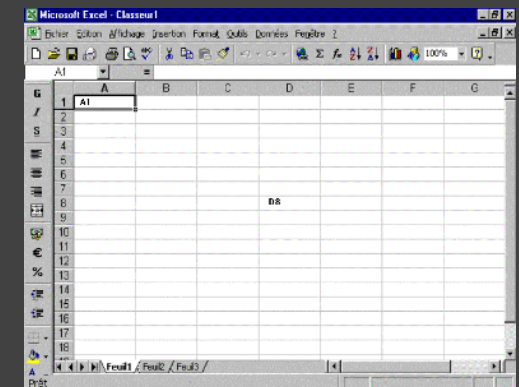
# Gulf of Execution

Gulf

Conceptual model:  
Draw a scatterplot



Real world



## **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]

# 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



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

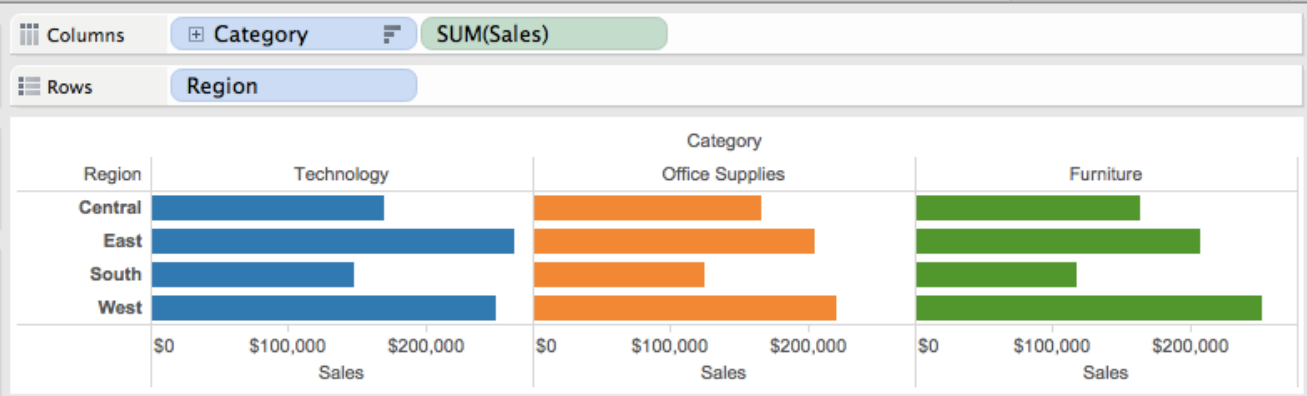
Color Size Label

Detail Tooltip

Category

Category

- Technology
- Office Supplies
- Furniture





Show Me

**Data** | Analytics

Sample - Superstore

**Dimensions**

- Customer
  - Customer Name
  - Segment
- Order
  - Location
- Product
  - Category
  - Sub-Category
  - Manufacturer
  - Product Name
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- Measure Names

**Measures**

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

**Pages**

**Columns** | Category | SUM(Sales)

**Rows** | Region

**Filters**

**Marks**

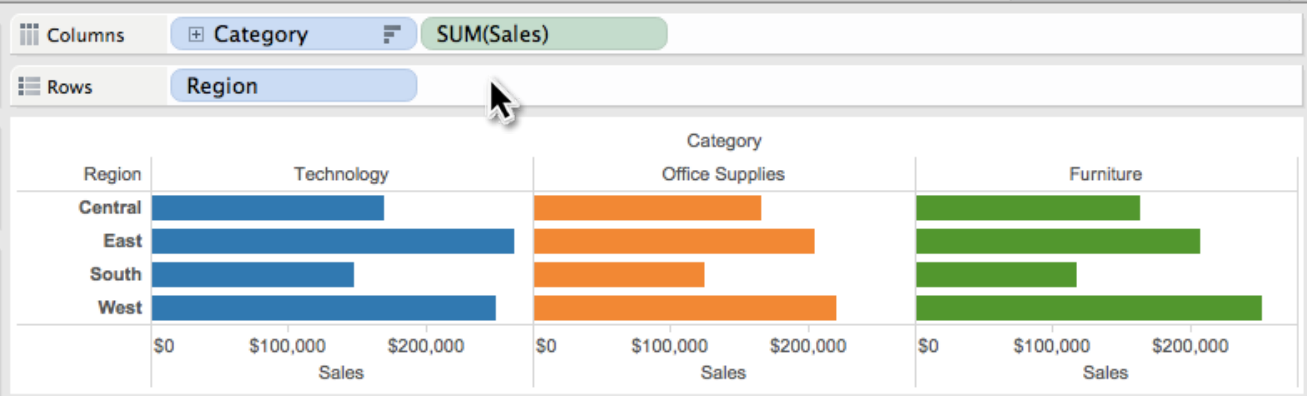
Automatic

Color | Size | Label

Detail | Tooltip

Category

Technology | Office Supplies | Furniture



**Data** | Analytics

Sample - Superstore

**Dimensions**

- Customer
  - Customer Name
  - Segment
- Order
- Location
- Product
  - Category
  - Sub-Category
  - Manufacturer
  - Product Name
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**Measures**

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

**Pages**

**Filters**

**Marks**

Automatic

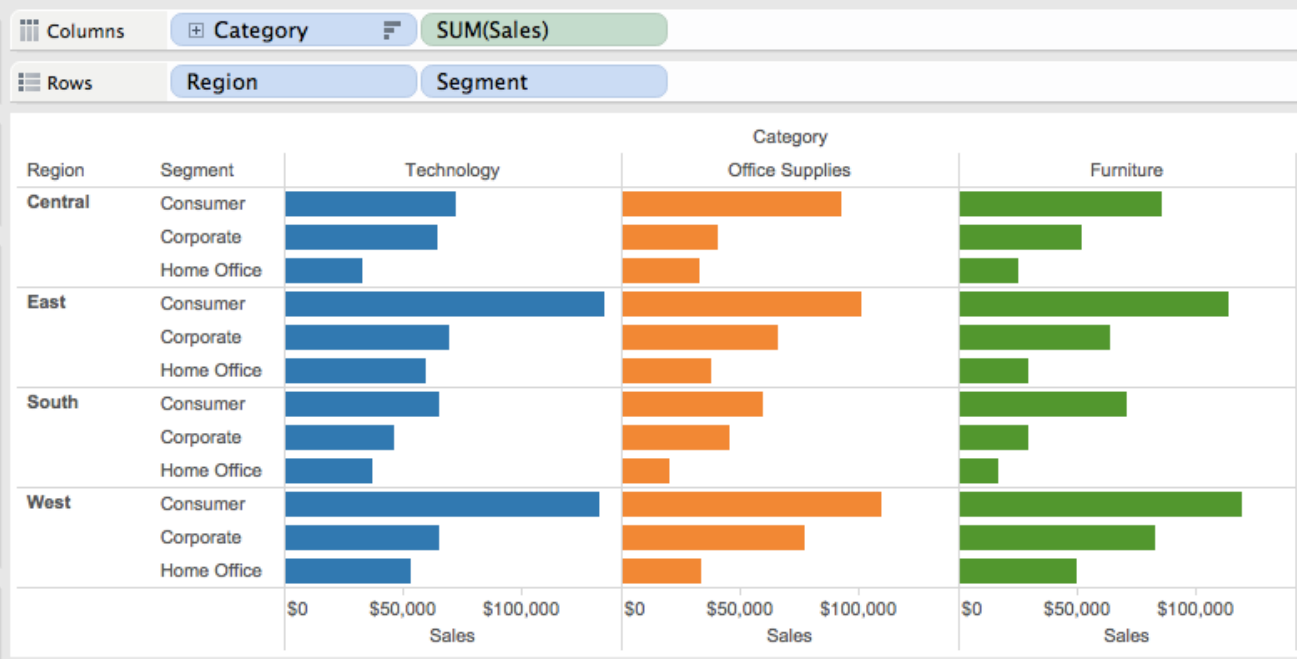
Color Size Label

Detail Tooltip

Category

Category

- Technology
- Office Supplies
- Furniture



**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**

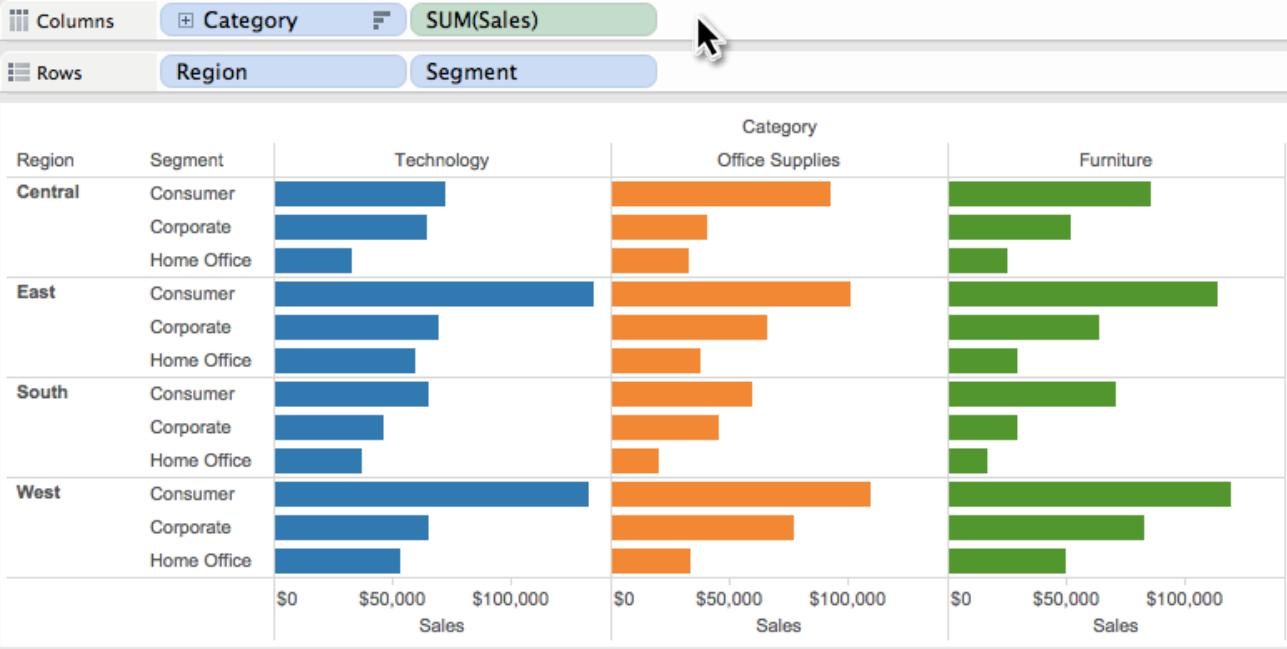
Automatic

Color Size Label

Detail Tooltip

Category

Technology Office Supplies Furniture



**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**

All

Automatic

Color Size Label

Detail Tooltip

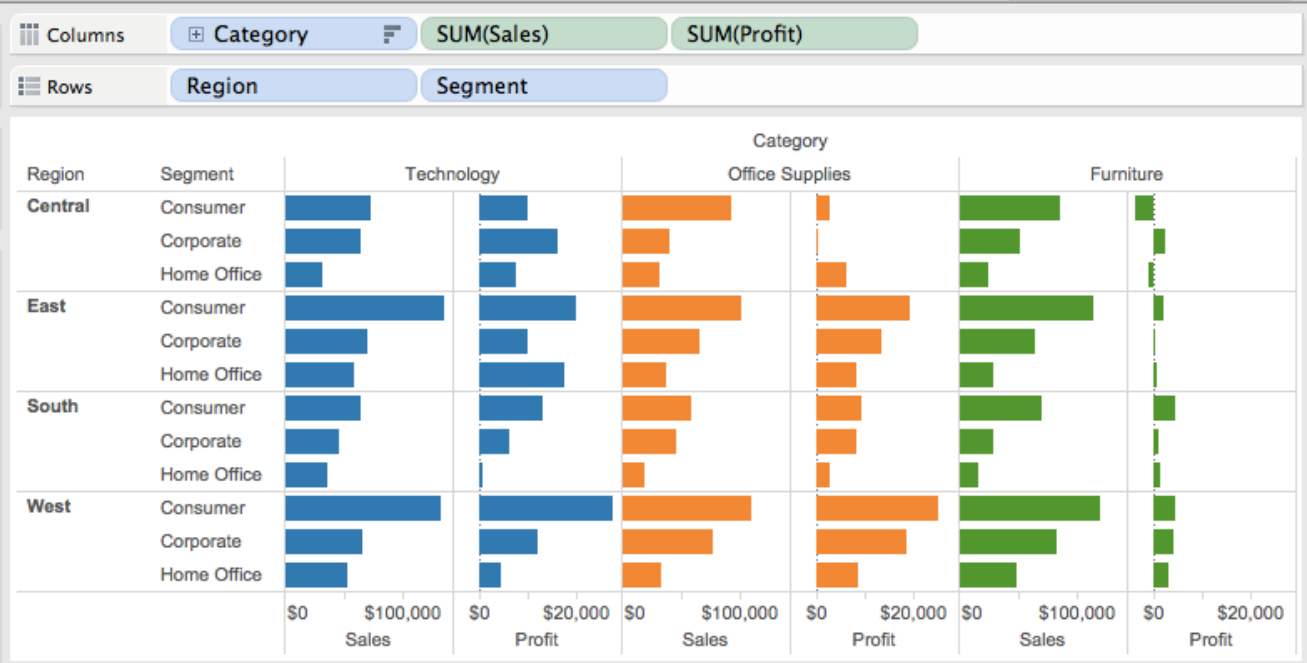
Category

SUM(Sales)

SUM(Profit)

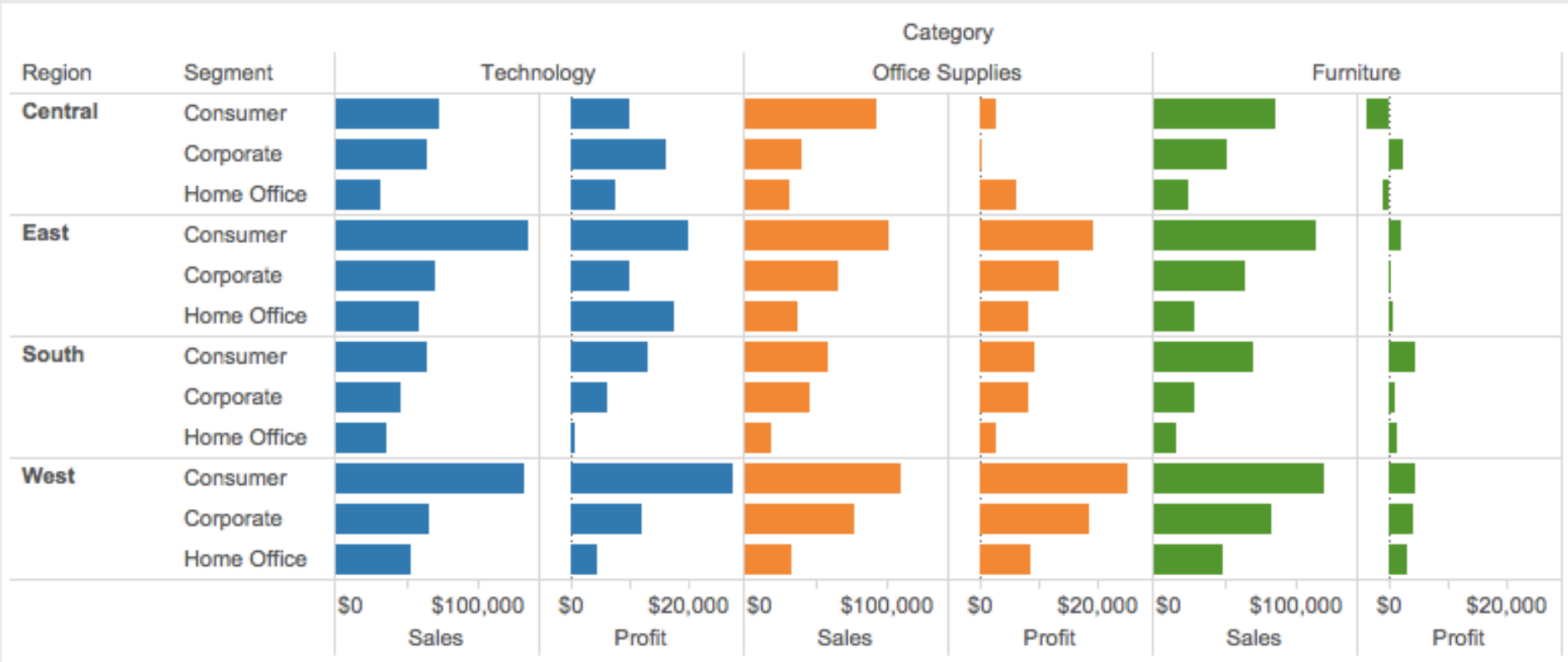
Category

- Technology
- Office Supplies
- Furniture



Columns **Category** ~~SUM(Sales)~~ **SUM(Profit)**

Rows **Region** **Segment**



# Taxonomy of Interactions

## Data and View Specification

Visualize, Filter, Sort, Derive



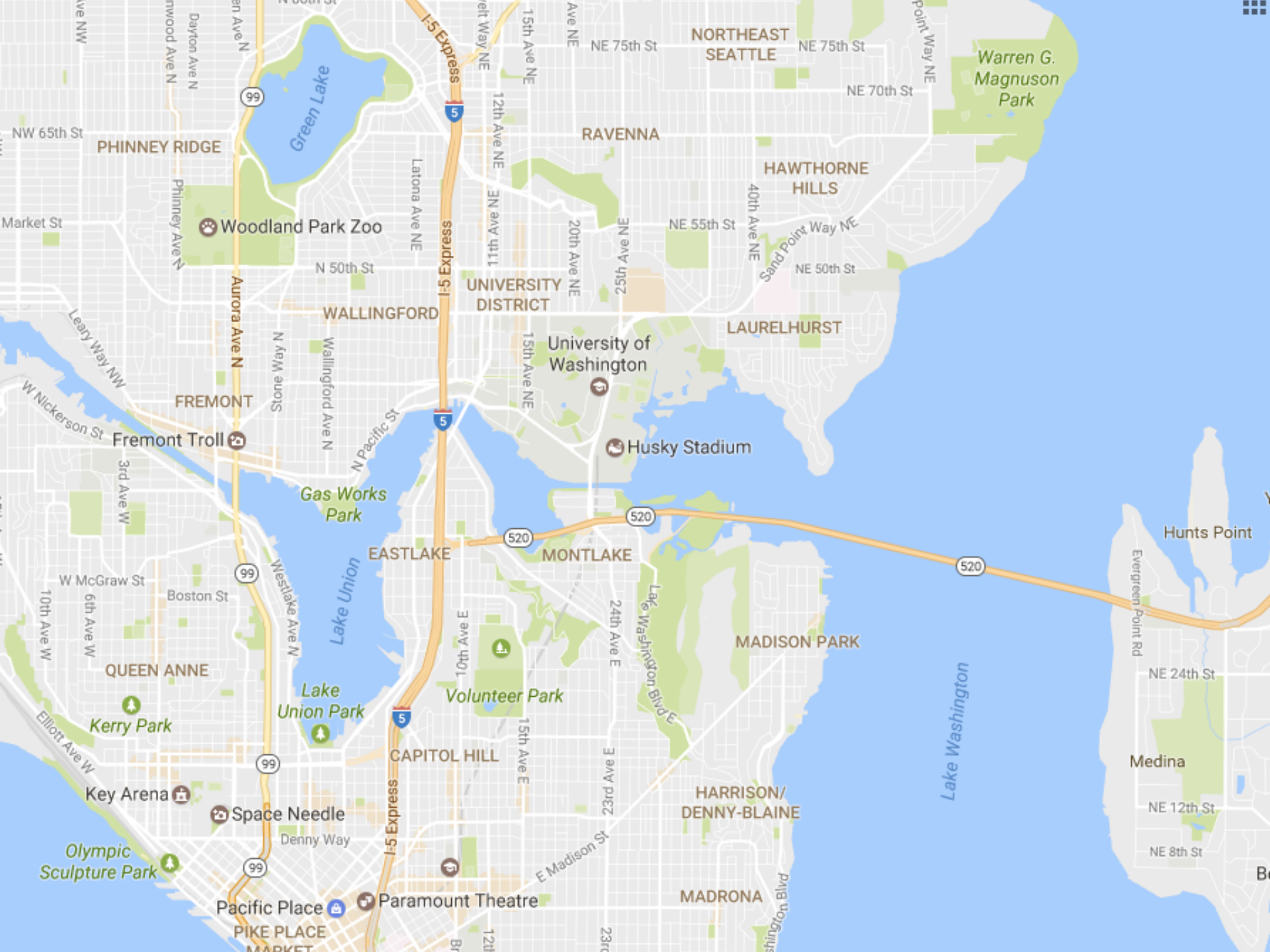
# Taxonomy of Interactions

## Data and View Specification

Visualize, Filter, Sort, Derive

## View Manipulation

Select, Navigate, Coordinate, Organize



NORTHEAST SEATTLE

Warren G. Magnuson Park

99

5

I-5 Express

PHINNEY RIDGE

Green Lake

RAVENNA

HAWTHORNE HILLS

Woodland Park Zoo

UNIVERSITY DISTRICT

University of Washington

LAURELHURST

WALLINGFORD

FREMONT

Fremont Troll

Husky Stadium

Gas Works Park

520

EASTLAKE

MONTLAKE

Hunts Point

520

MADISON PARK

Lake Union

Lake Union Park

Volunteer Park

520

QUEEN ANNE

Kerry Park

CAPITOL HILL

HARRISON/DENNY-BLAINE

Medina

Space Needle

Olympic Sculpture Park

Paramount Theatre

MADRONA

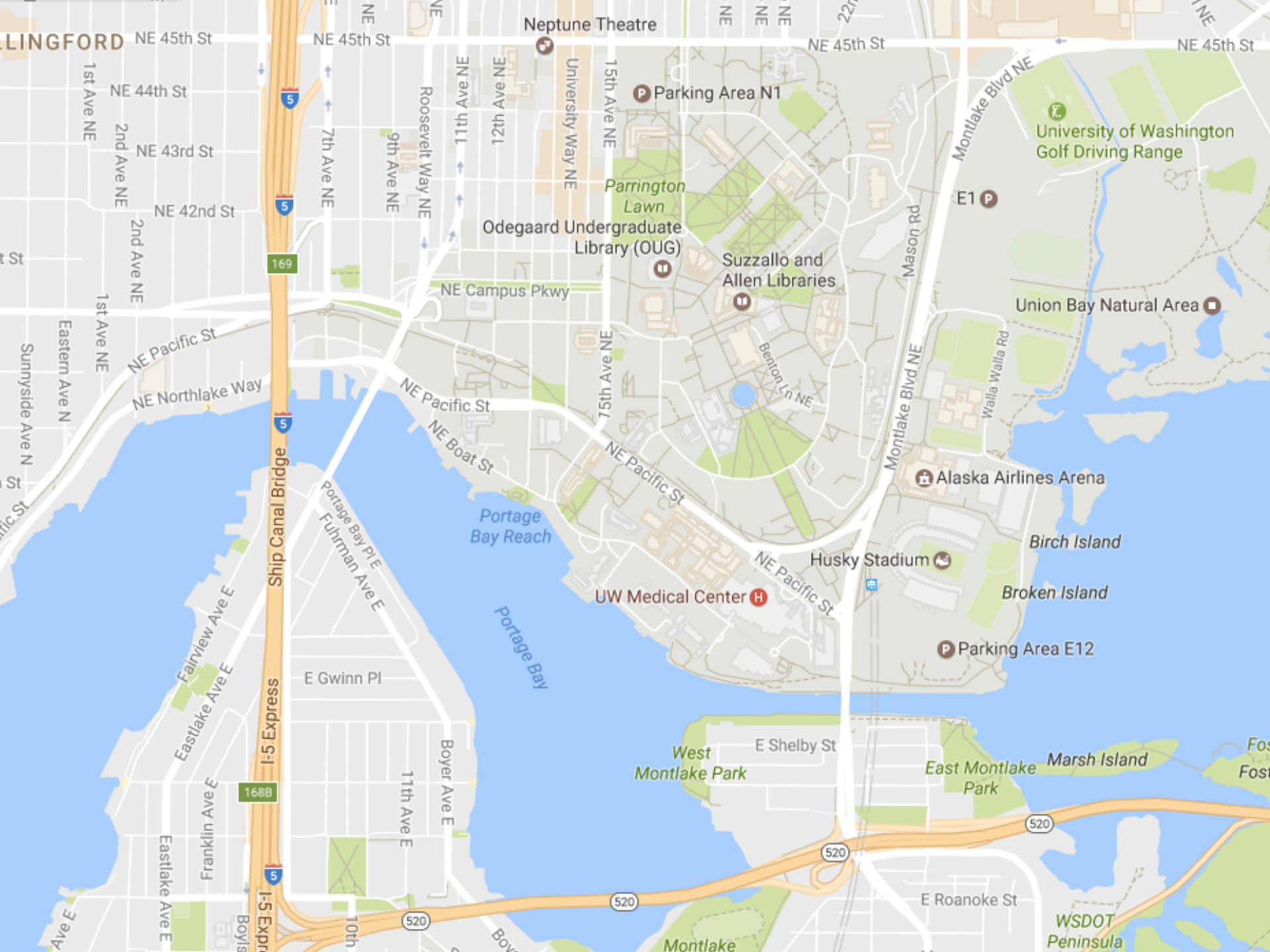
Pacific Place

PIKE PLACE MARKET

NE 12th St

NE 8th St

Lake Washington



# 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

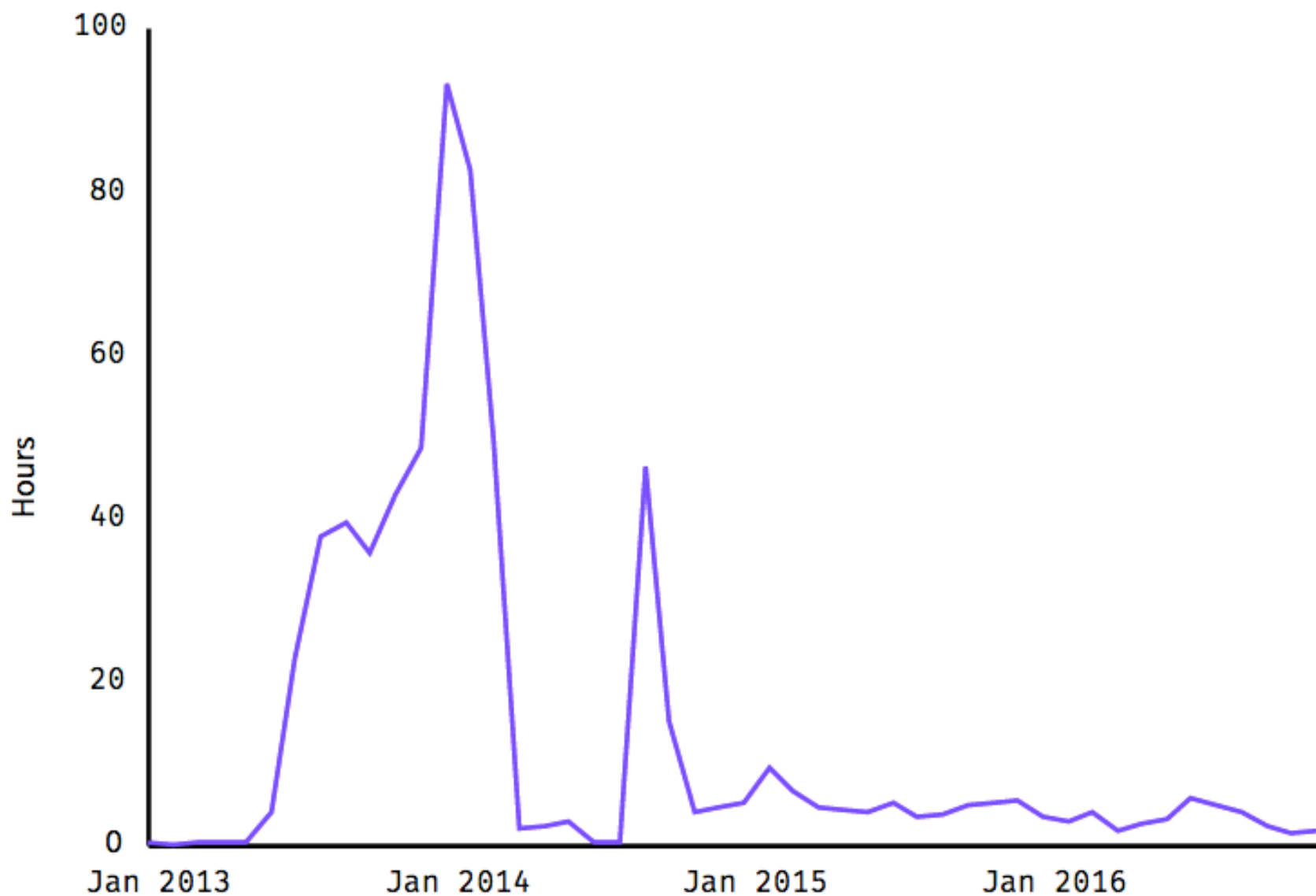
## View Manipulation

Select, Navigate, Coordinate, Organize

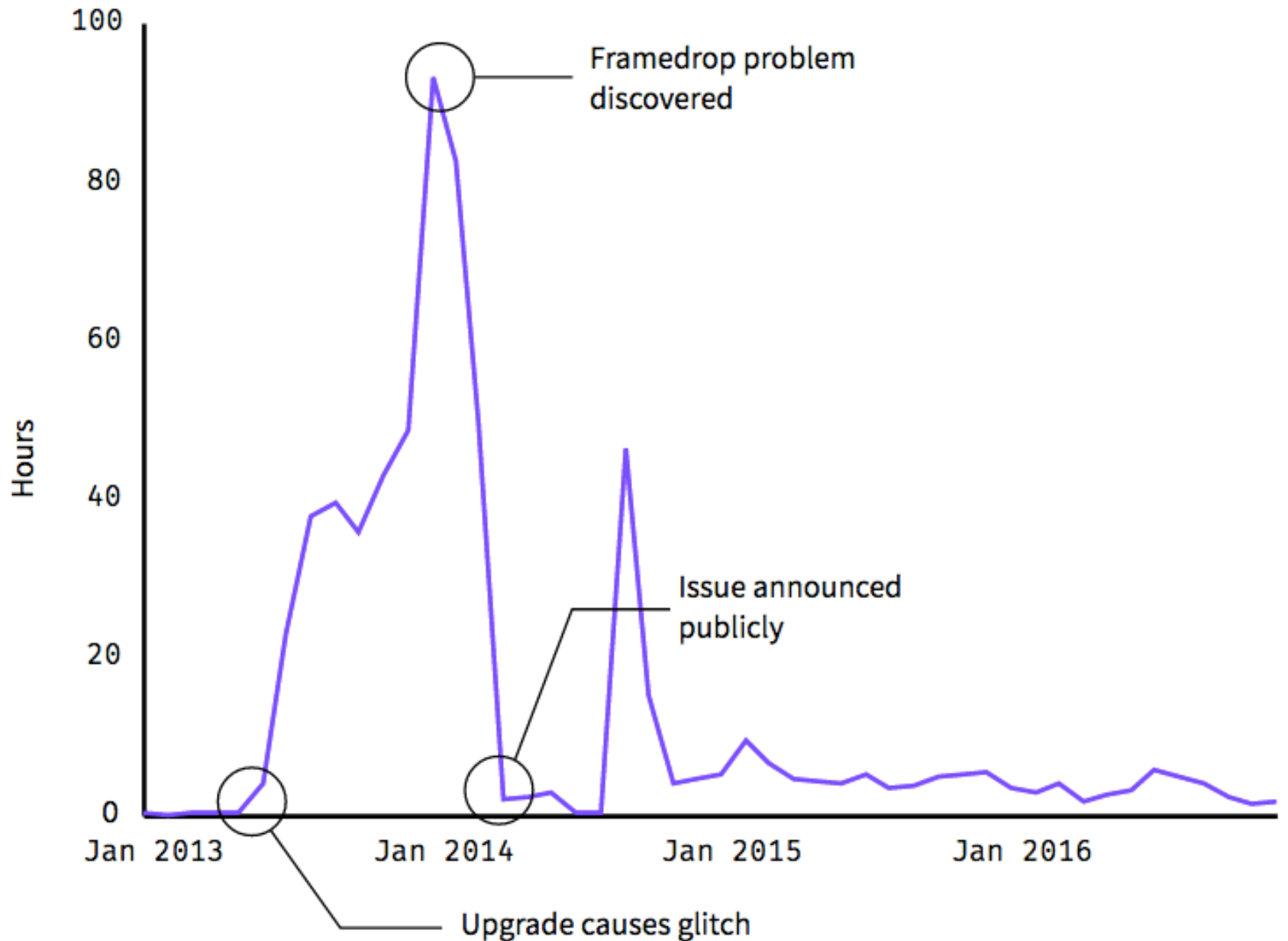
## Process and Provenance

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

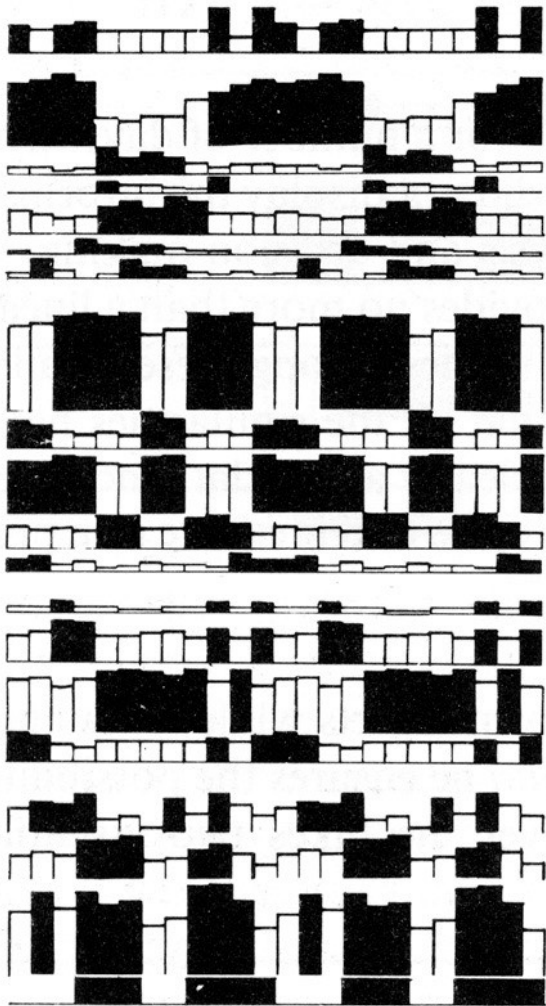


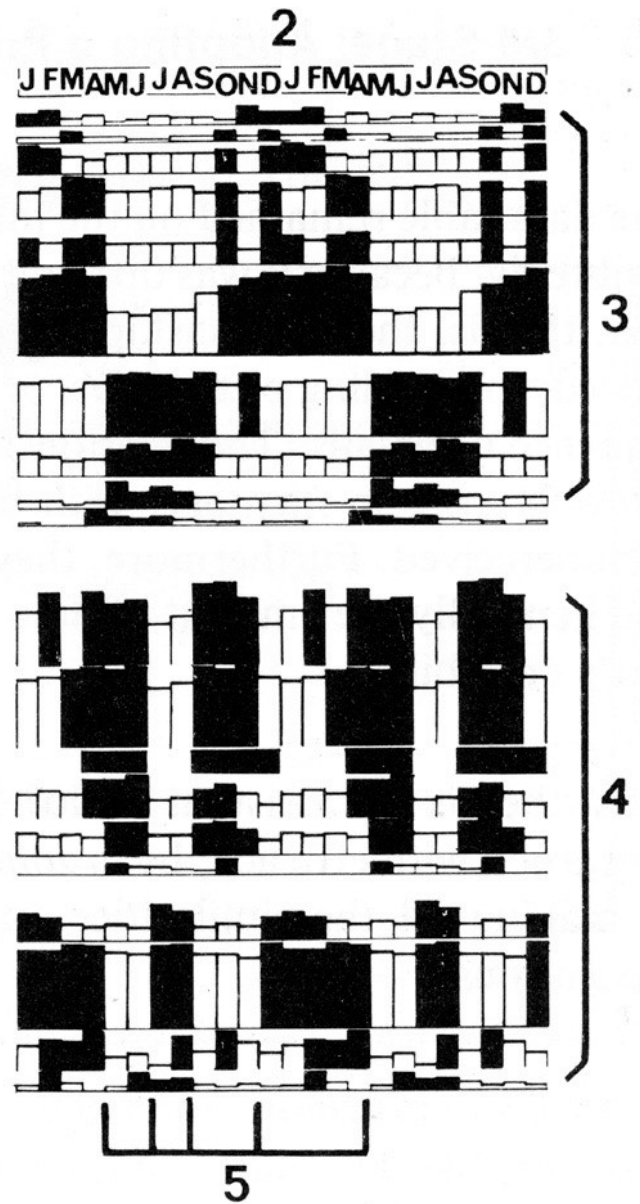
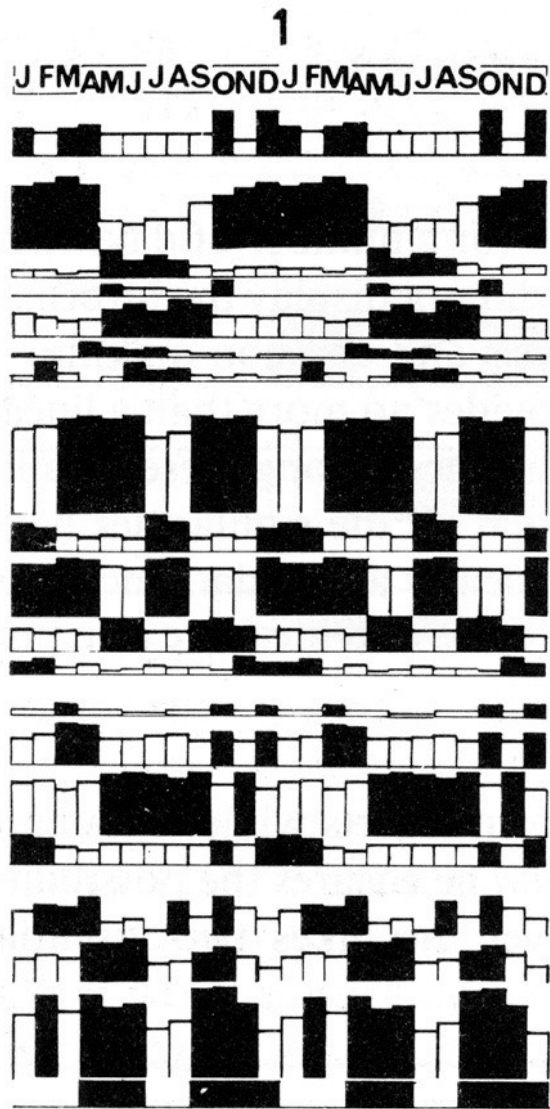
**EXAMPLE:**  
**Bertin's Hotel Data**

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	51	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

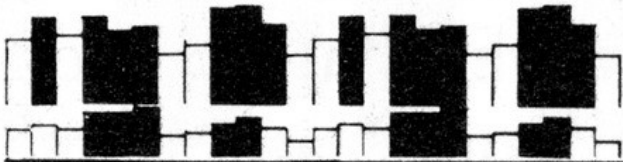
1

J FMAMJ JASONDJ FMAMJ JASOND



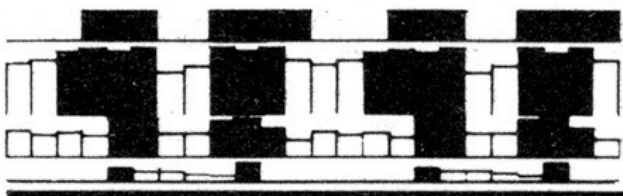


J F M A M J J A S O N D J F M A M J J A S O N D



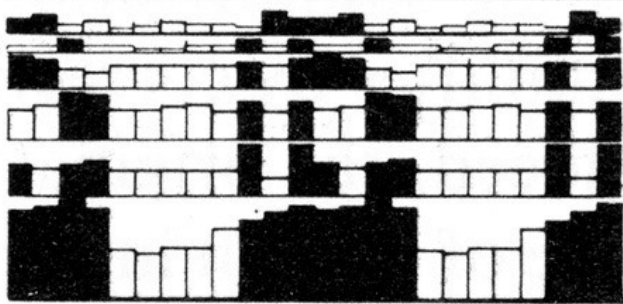
18 % OCCUPANCY  
18 LENGTH OF STAY

ACTIVE AND SLOW PERIODS



20 CONVENTIONS  
8 BUSINESSMEN  
11 AGENCY RESERVATIONS  
4 SOUTH AMERICA

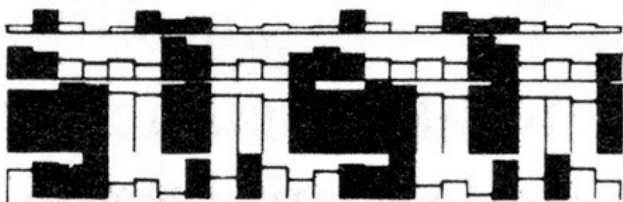
DISCOVERY FACTORS



18 AIR CREWS  
18 CLIENTS UNDER 20 YEARS  
18 CLIENTS MORE THAN 55 YEARS  
14 CLIENTS FROM 20-35 YEARS  
1 FEMALE CLIENTELE  
2 LOCAL CLIENTELE

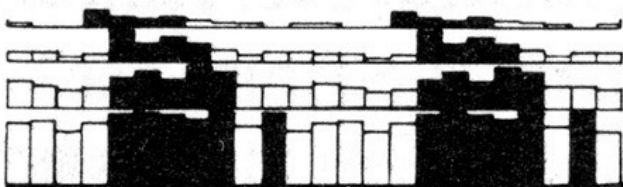
RECOVERY FACTORS

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]



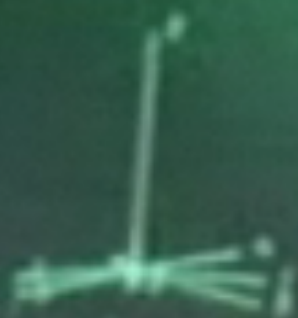
**EXAMPLE:**

**Tukey et al.'s PRIM-9**



PRIM-9, Tukey, Fisherkeller, Friedman 1972

L.



|

|

1 200 400  
175 5

8 175 25 275

1000-275 25 25

7 1 200 400

175  
1 1 200 400

L,



# Selection

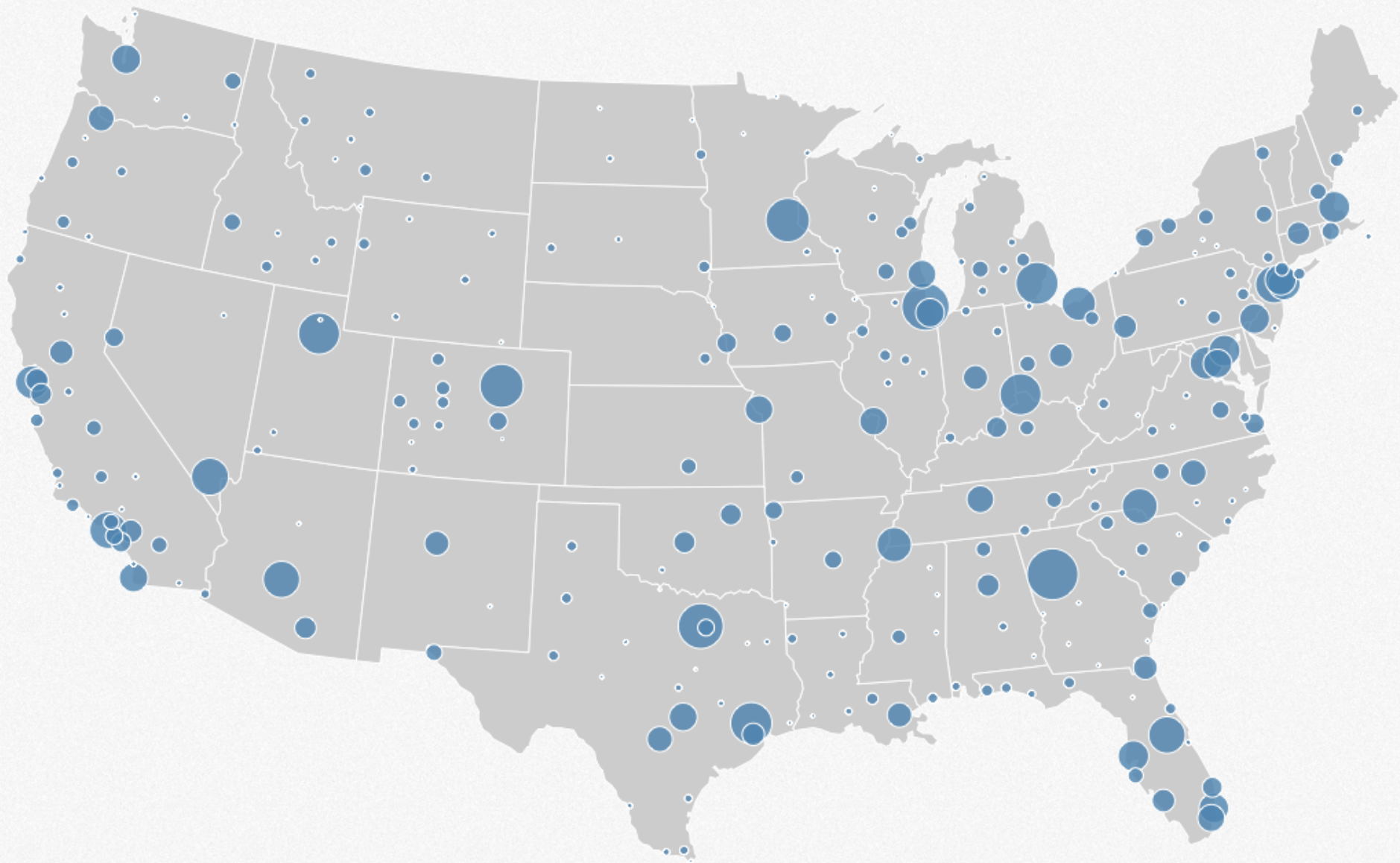
# Basic Selection Methods

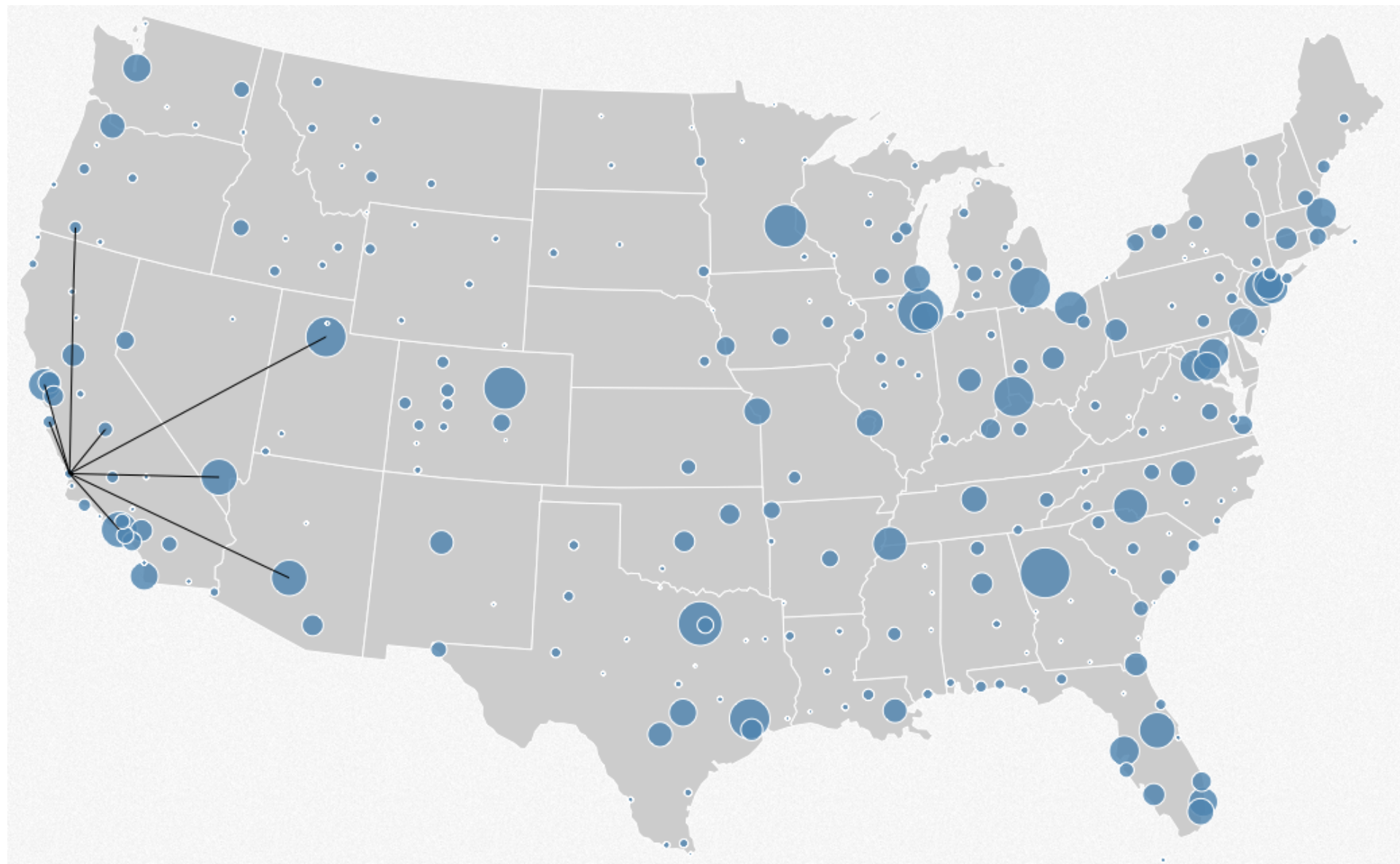
## Point Selection

Mouse Hover / Click

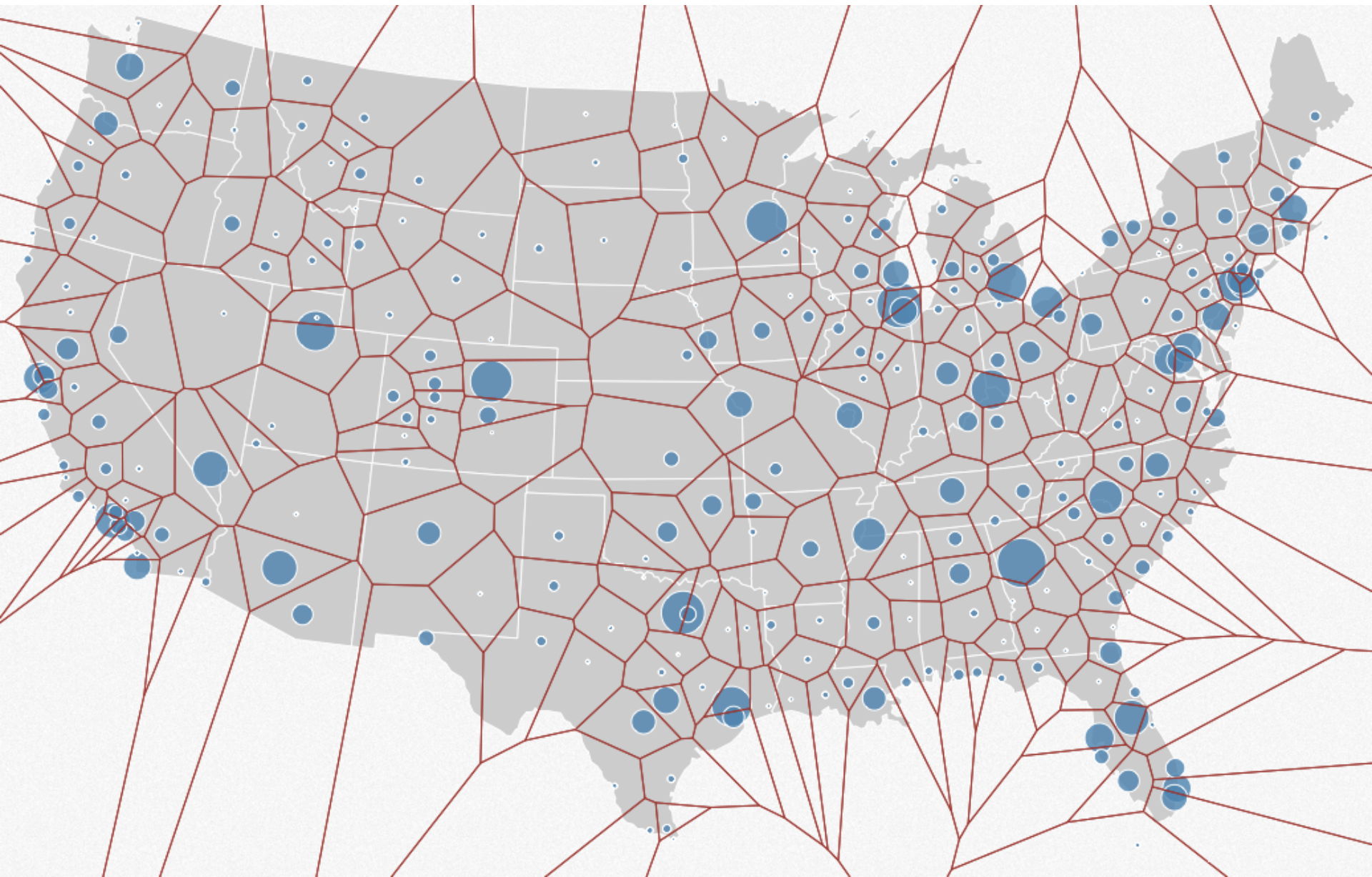
Touch / Tap

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

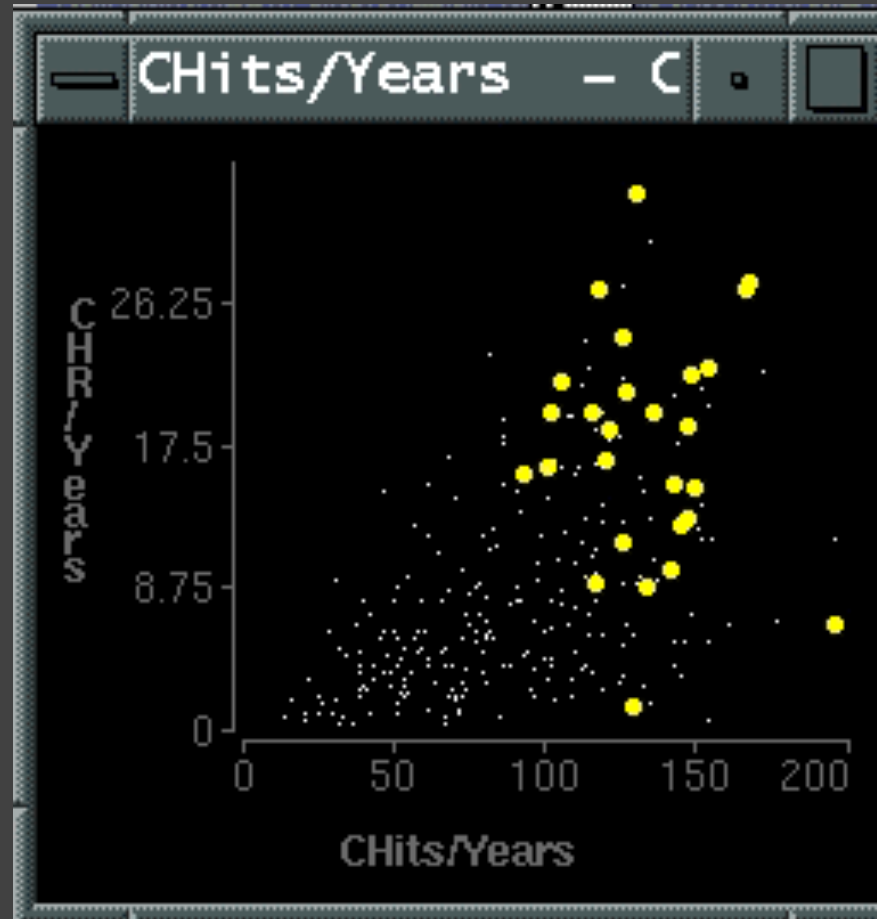
Rubber-band (rectangular) or Lasso (freehand)

Area cursors ("brushes")

# Brushing & Linking

# Brushing

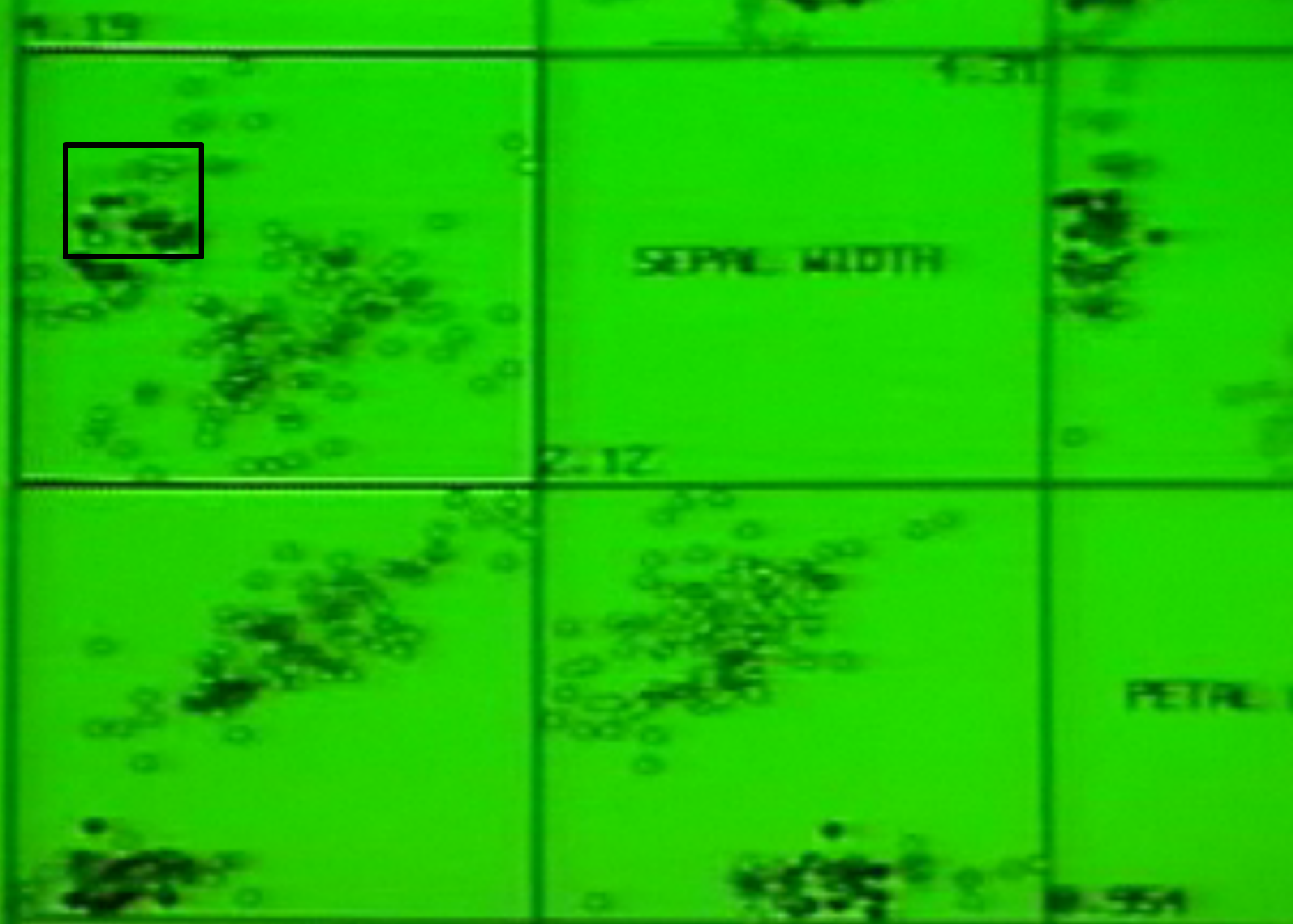
Direct attention to a subset of data [Wills 95]



# Brushing & Linking

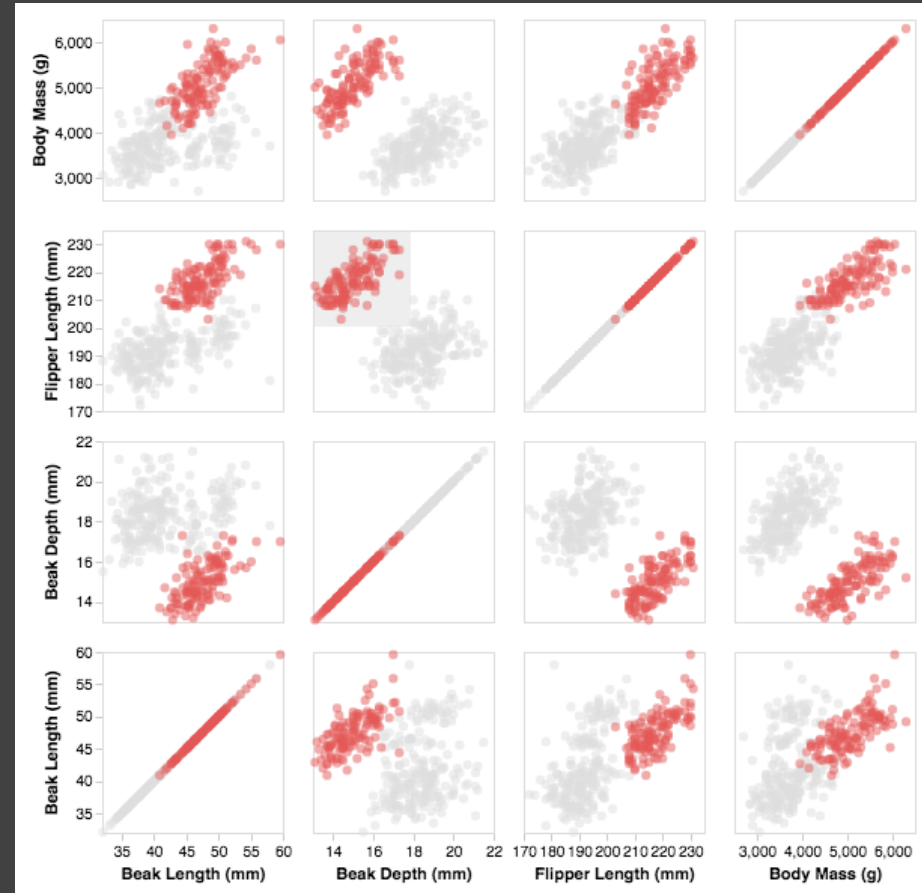
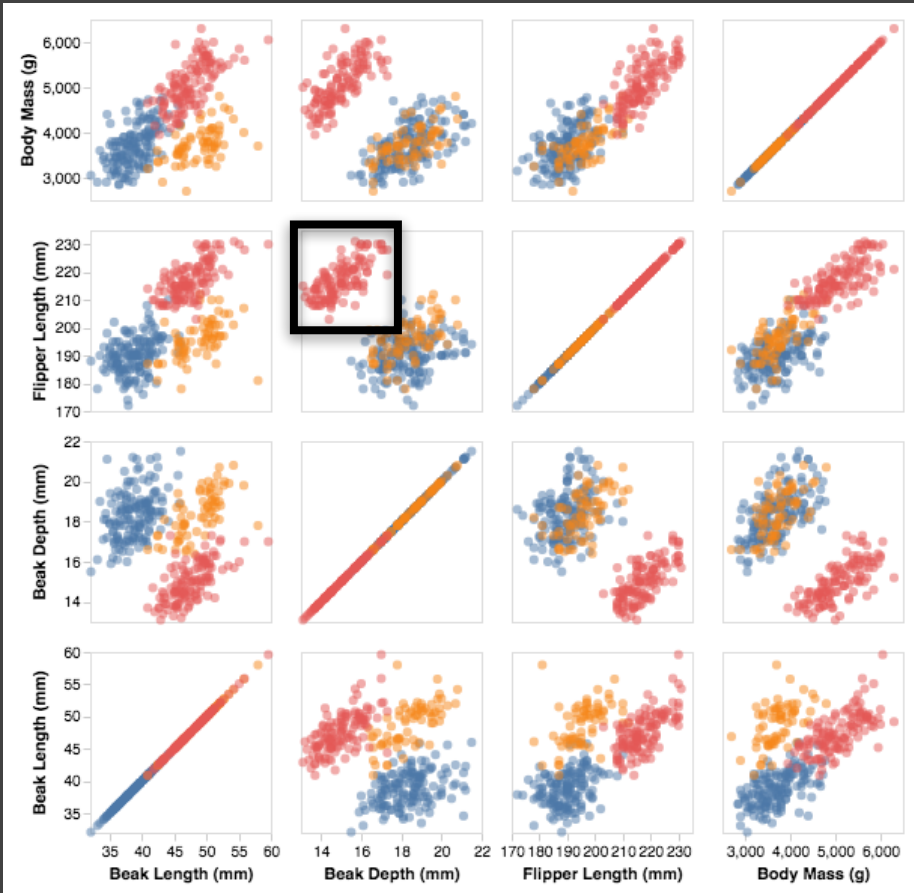
Select ("**brush**") a subset of data  
See selected data in other views

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



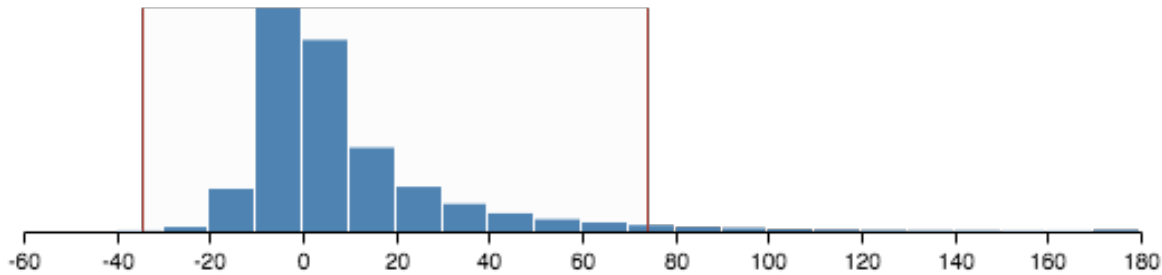
Brushing Scatterplots, Becker & Cleveland 1982

# Brushing Scatterplots

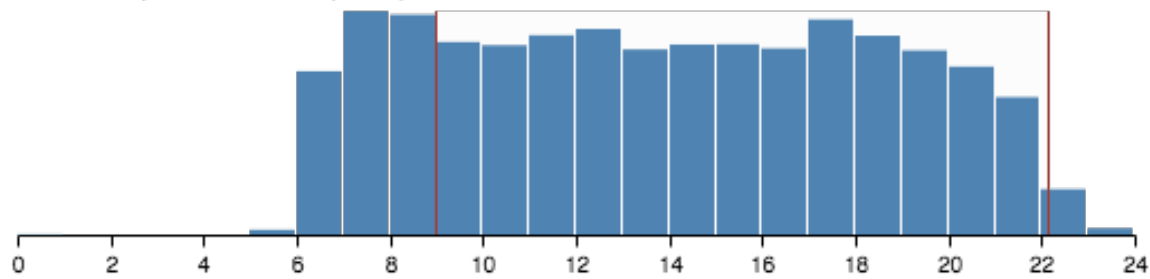


# Cross-Filtering

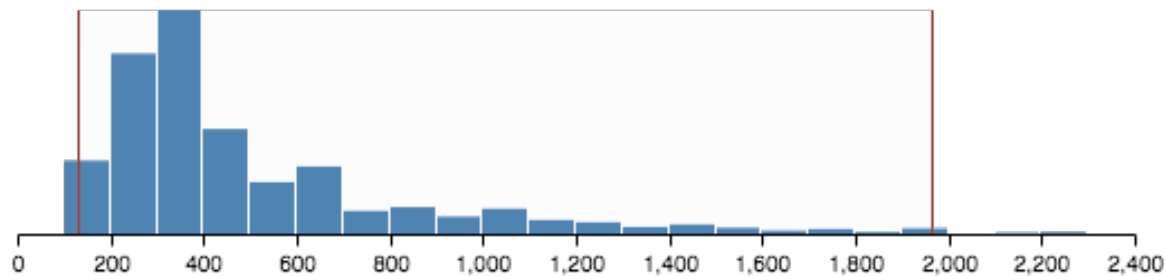
Arrival Delay (min)



Local Departure Time (hour)

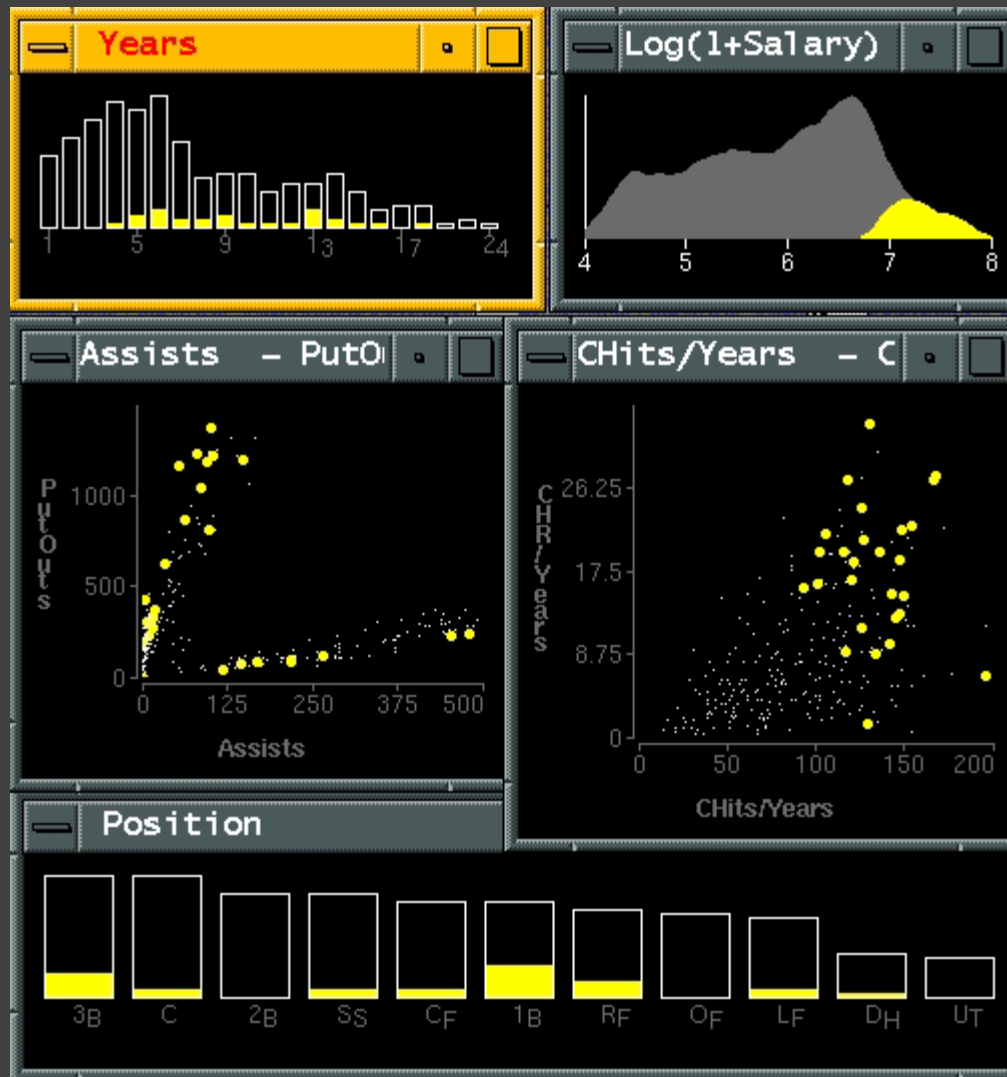


Travel Distance (miles)

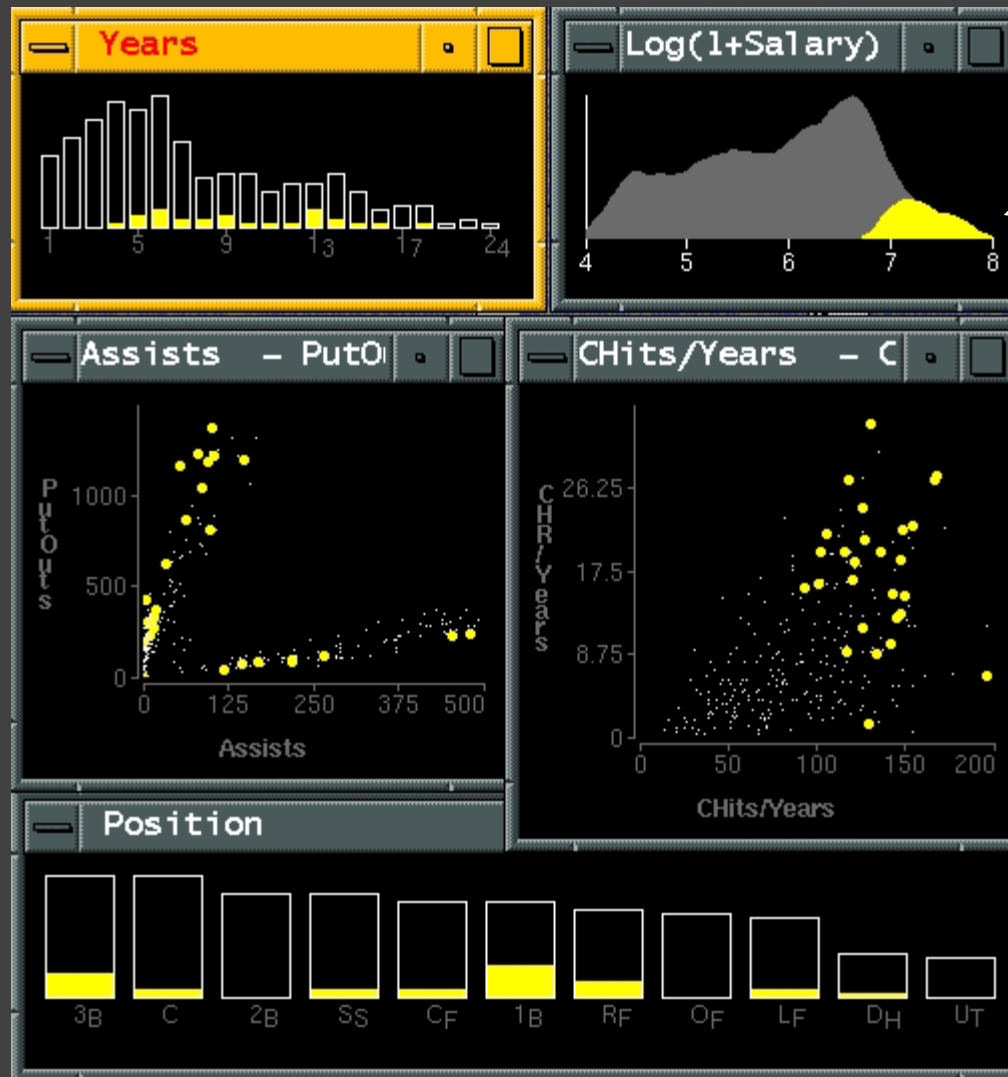




# Baseball Statistics [Wills 95]

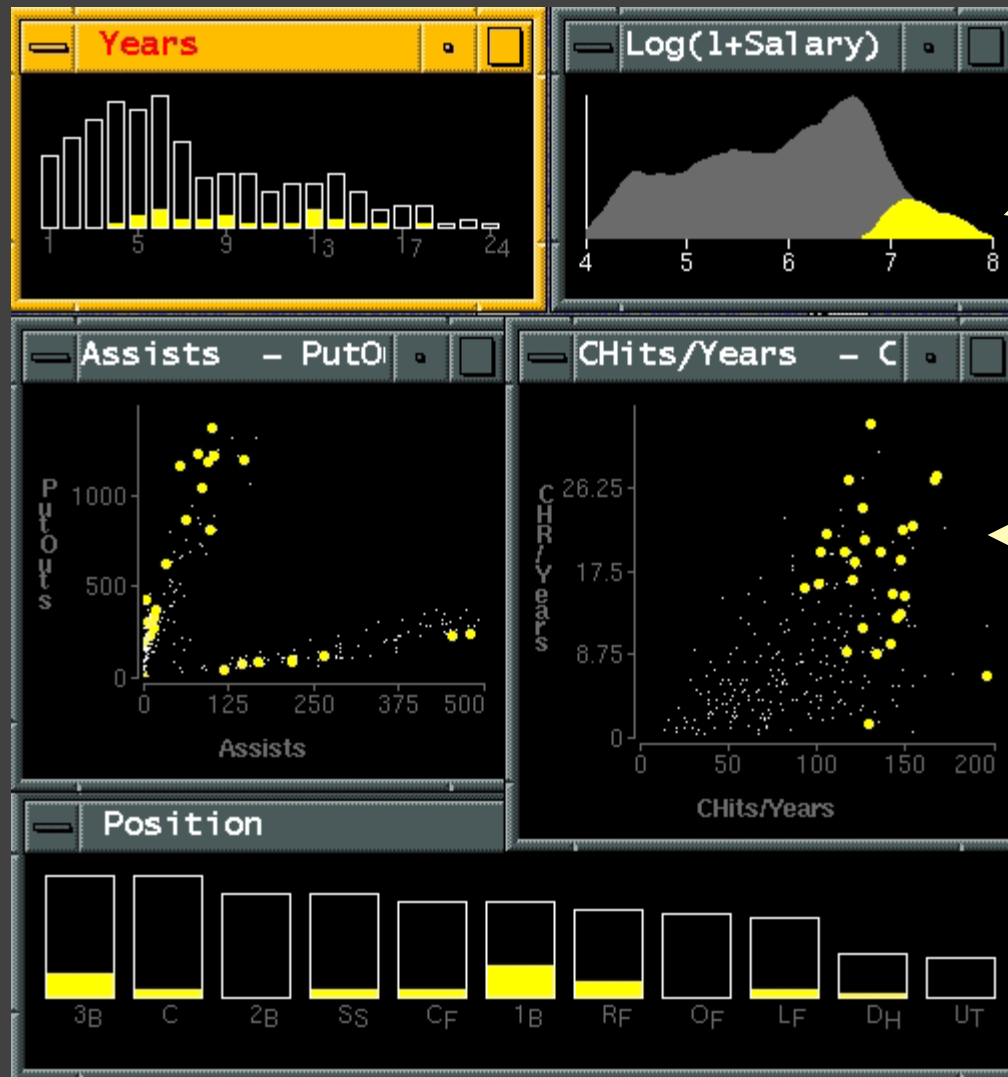


# Baseball Statistics [Wills 95]



select high salaries

# Baseball Statistics [Wills 95]

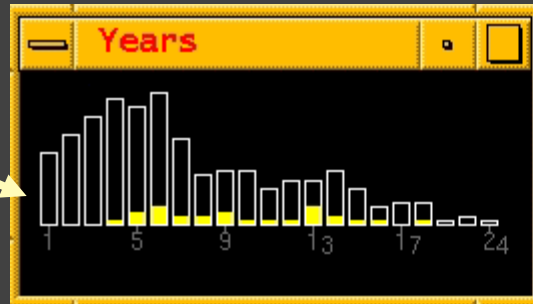


select high salaries

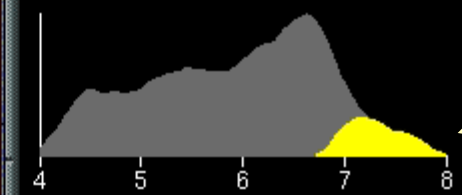
avg career HRs vs avg career hits (batting ability)

# Baseball Statistics [Wills 95]

how long  
in majors

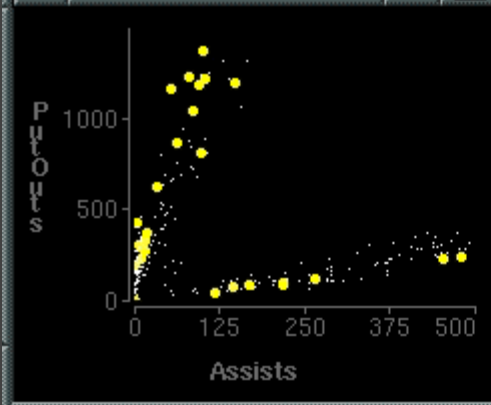


Log(1+Salary)

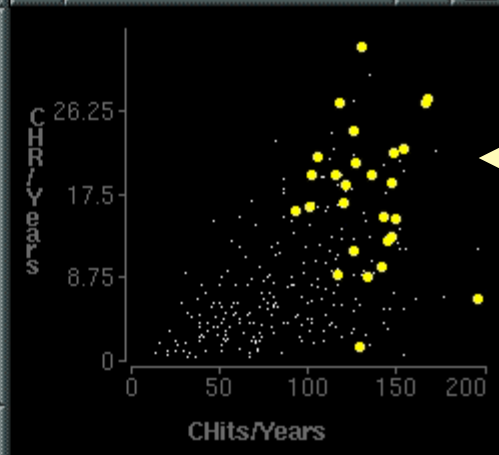


select high  
salaries

Assists - PutO

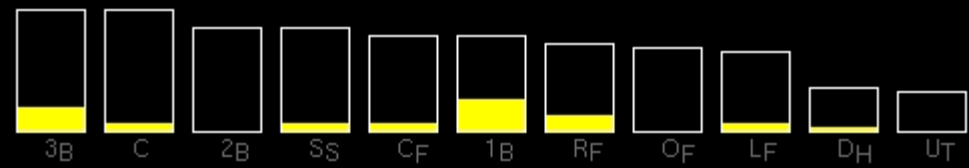


CHits/Years - C



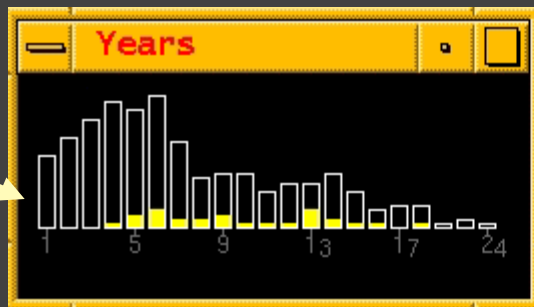
avg career  
HRs vs avg  
career hits  
(batting ability)

Position

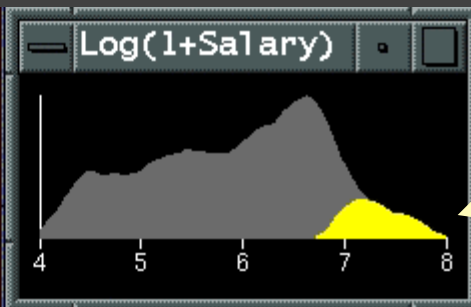


# Baseball Statistics [Wills 95]

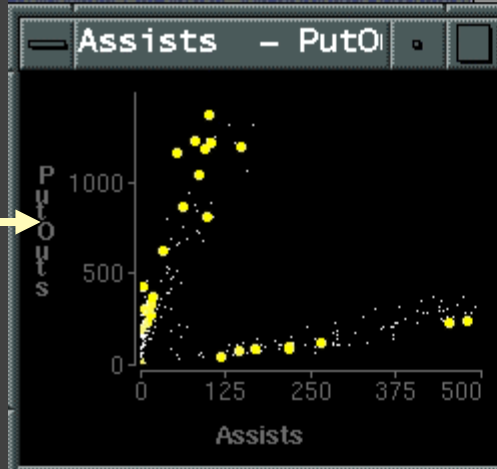
how long  
in majors



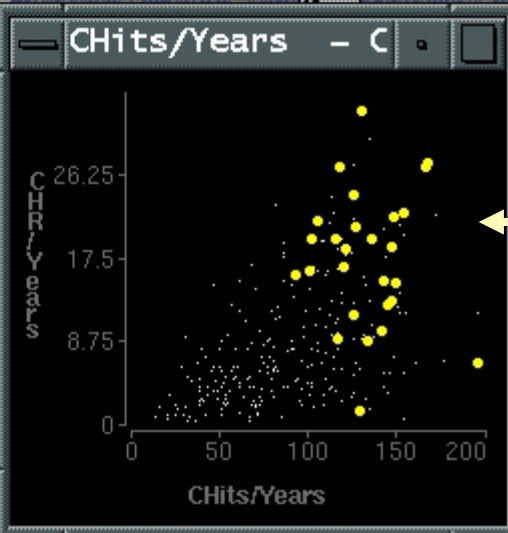
select high  
salaries



avg assists vs  
avg putouts  
(fielding ability)

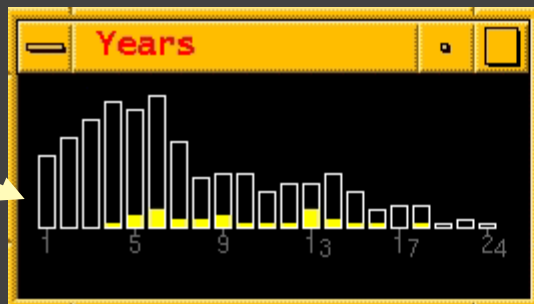


avg career  
HRs vs avg  
career hits  
(batting ability)

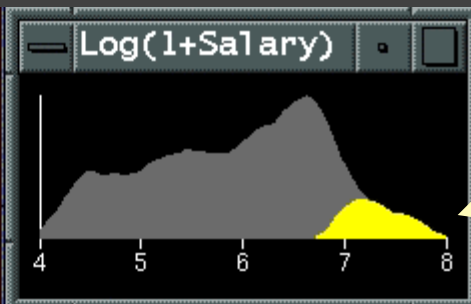


# Baseball Statistics [Wills 95]

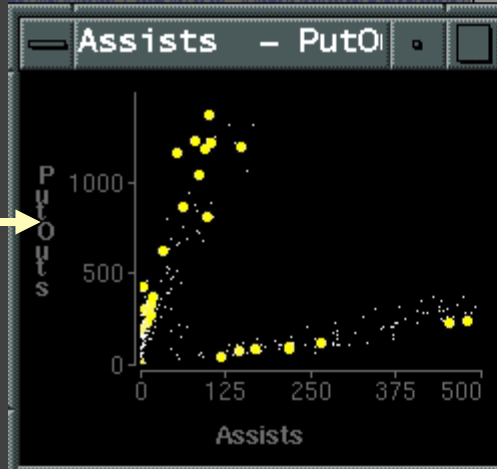
how long  
in majors



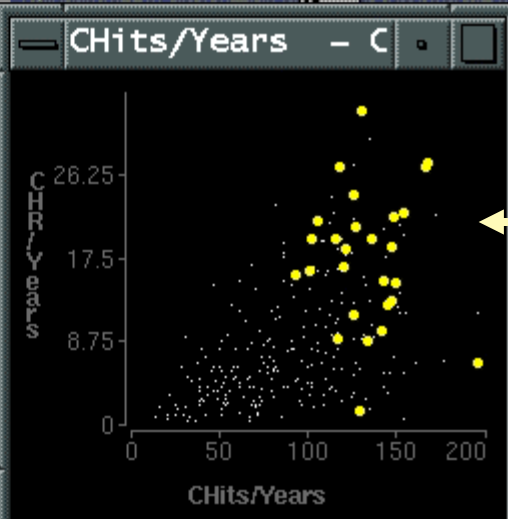
select high  
salaries



avg assists vs  
avg putouts  
(fielding ability)



avg career  
HRs vs avg  
career hits  
(batting ability)



distribution  
of positions  
played



# 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

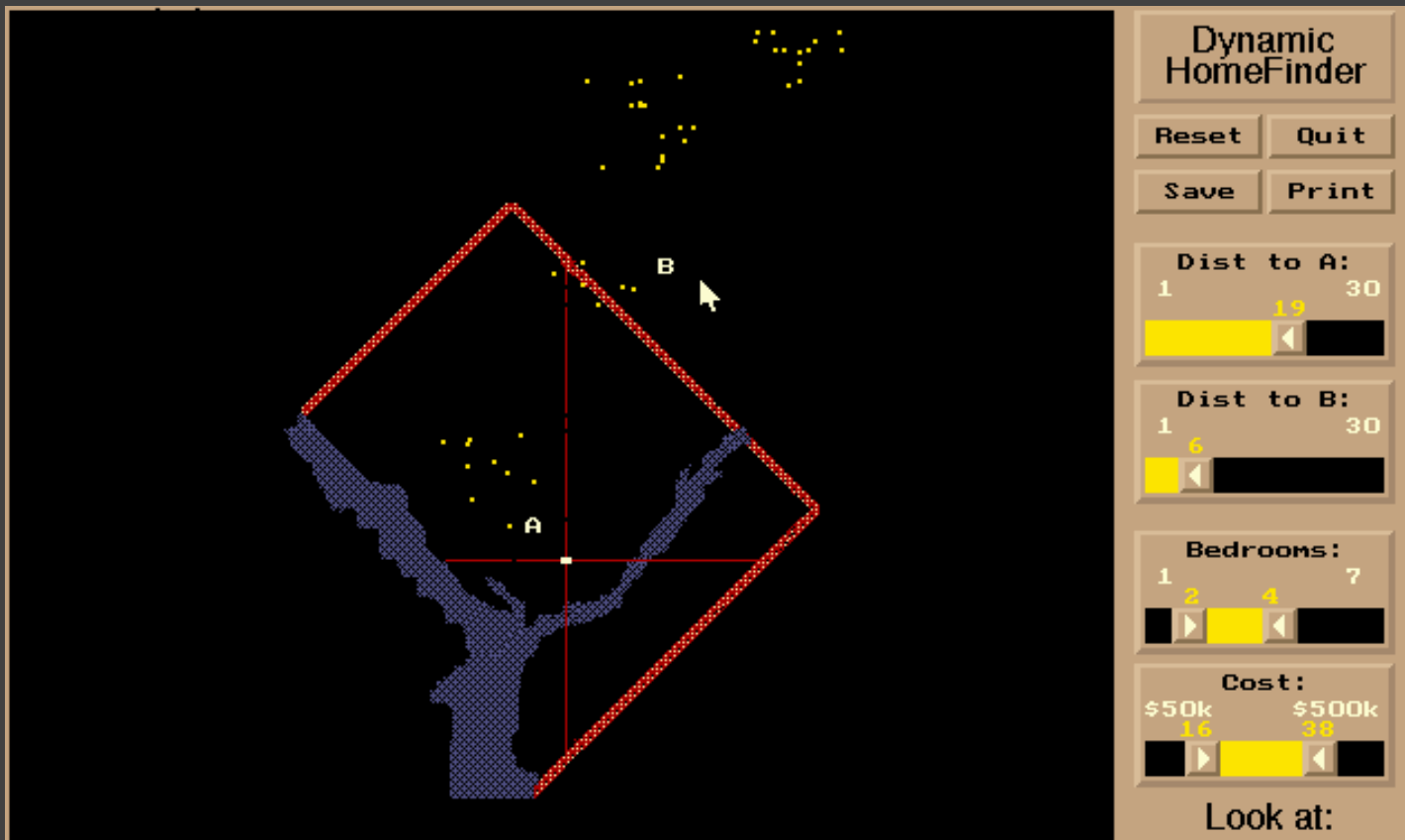
Given housing data with:

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

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

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

# HomeFinder



The yellow dots above are homes in the DC area for sale. You may get more information on a home by selecting it.

You may drag the 'A' and 'B' distance markers to your office or any other location you want to live near.

Select distances, bedrooms, and cost ranges by dragging the corresponding slider boxes on the right.

Select specific home types and services by pressing the labeled buttons on the right.

**Dynamic HomeFinder**

Reset Quit

Save Print

Dist to A:  
1 30  
19

Dist to B:  
1 30  
6

Bedrooms:  
1 2 4 7

Cost:  
\$50k \$500k  
16 38

Look at:  
Hse TH Cnd

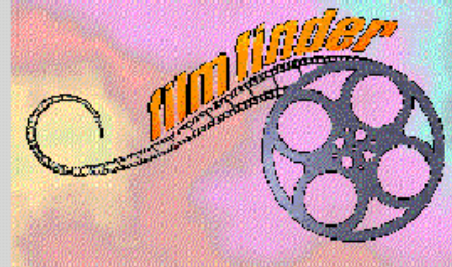
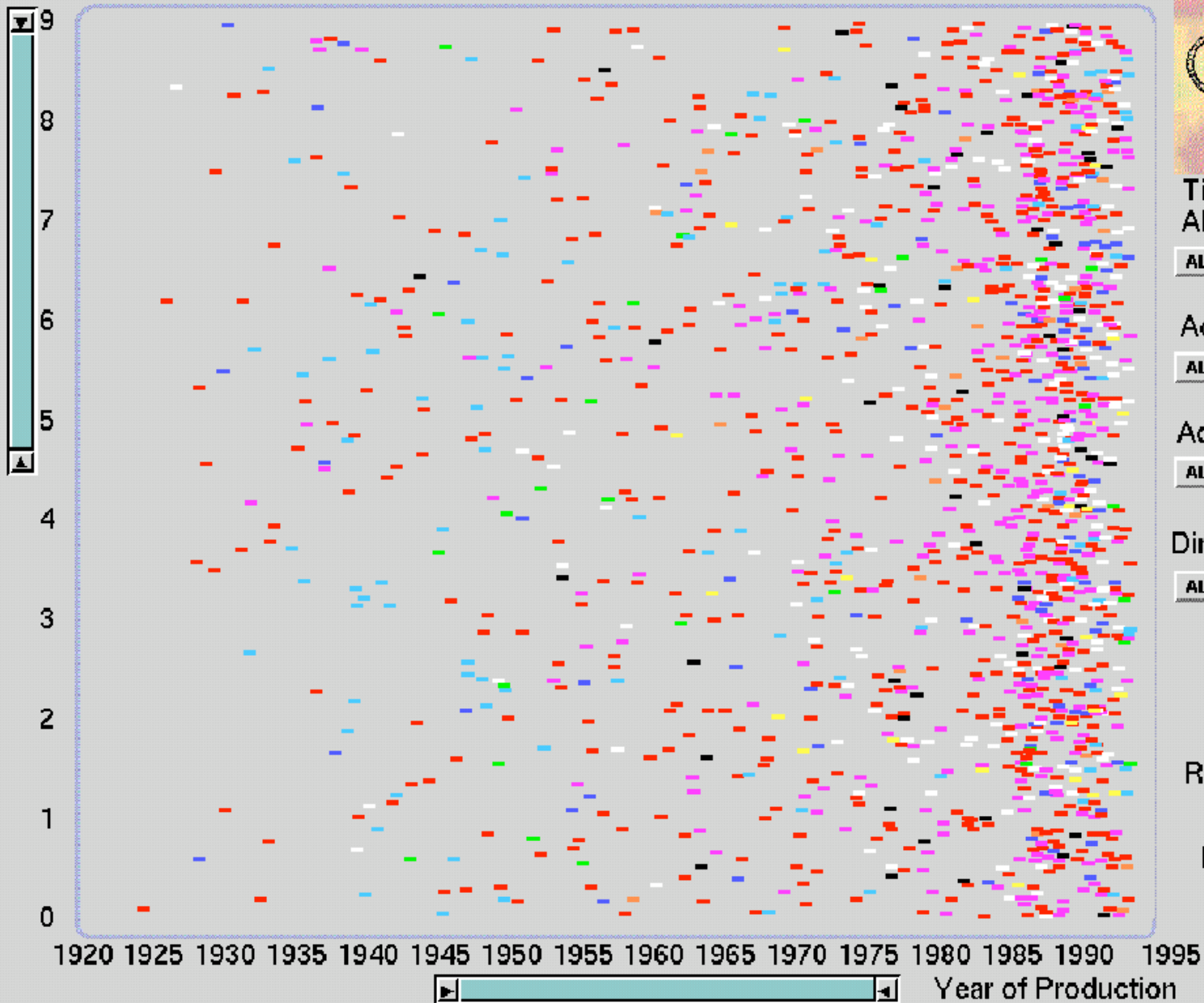
Features:  
Grg Fp1  
CAC New

[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   
 ABCDFGHLMNPRSTWZ

Actor : ALL  
 ALL   
 ABCDFGHJKLM PRSTWZ

Actress : ALL  
 ALL   
 ABCDFGHJKLM PRSTWZ

Director : ALL  
 ALL   
 ABCDFGHJKLM PRSTWZ

0 Length 450

0 450

Ratings  G  PG  
 PG-13  R

Films Shown: 1455

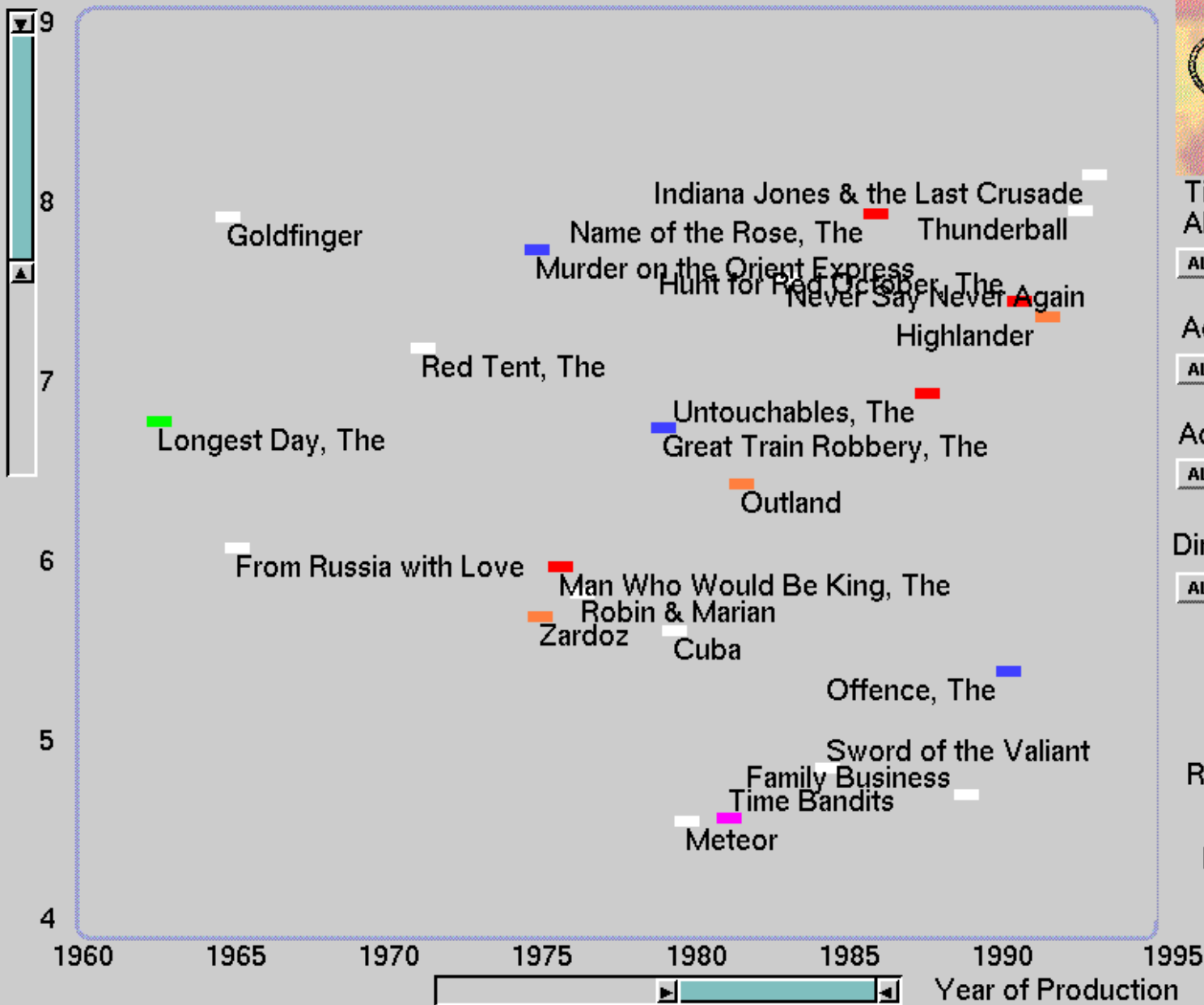


Copyright (C) 1993 HCIL

- ALL
- Drama
- Mystery
- Comedy
- Music
- Action
- War
- Sci-Fi
- Western
- Horror

[Ahlberg and Shneiderman 94]

Popularity



Title : ALL

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

Actor : Connery, Sean

ALL    
AB C D FG H J K L M PR S TW Z

Actress : ALL

ALL    
AB C D FGH K L M P R S TW Z

Director : ALL

ALL    
AB C D FGH JKL M PR S TW Z

60 Length 269

0 450

Ratings  G  PG  PG-13  R

Films Shown: 24



Copyright (C) 1993 HCIL

- ALL
- Drama
- Mystery
- Comedy
- Music
- Action
- War
- Sci-Fi
- Western
- Horror

# Alphaslider (?)

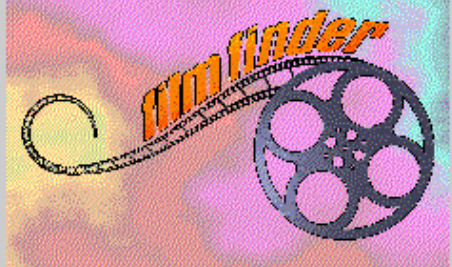
Title :

Moonstruck

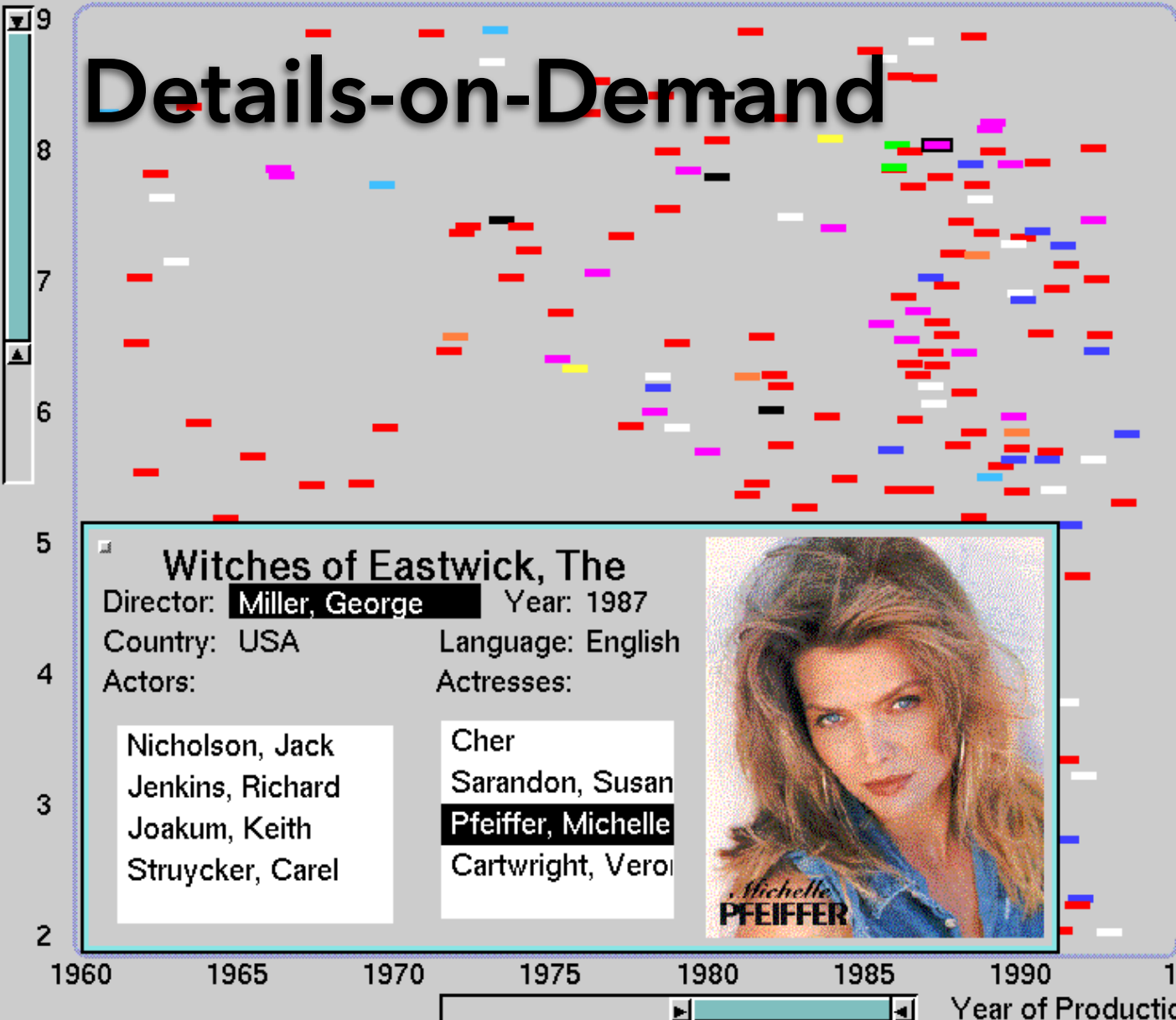
ALL

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





# Details-on-Demand



## 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



Title :

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

Actor : ALL

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

Actress : Pfeiffer, Michelle

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

Director : Miller, George

ALL   ALL  
 A B 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

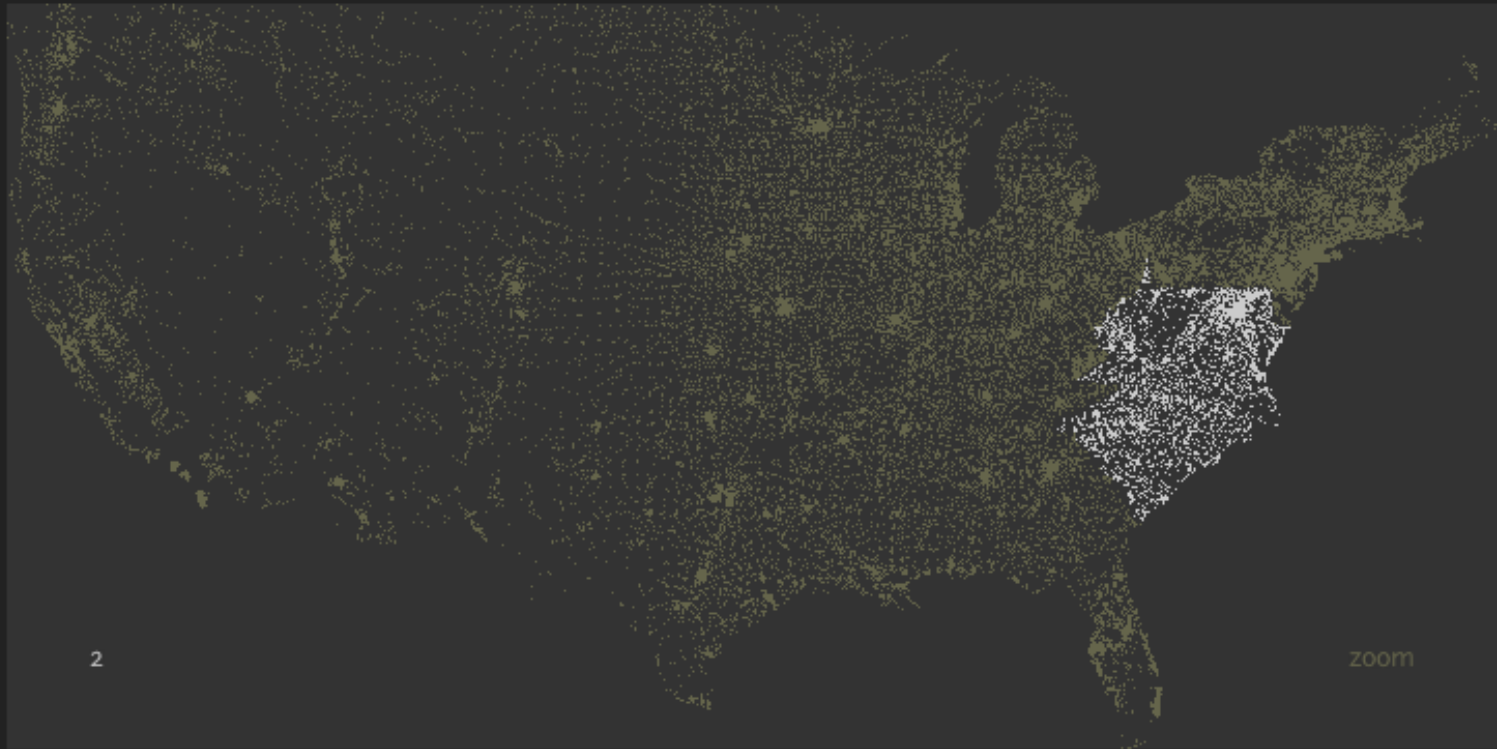


Copyright (C) 1993 HCIL

- ALL
- Drama
- Mystery
- Comedy
- Music
- Action
- War
- Sci-Fi
- Western
- Horror

- The Attribute Explorer

# Zipdecode [Fry 04]

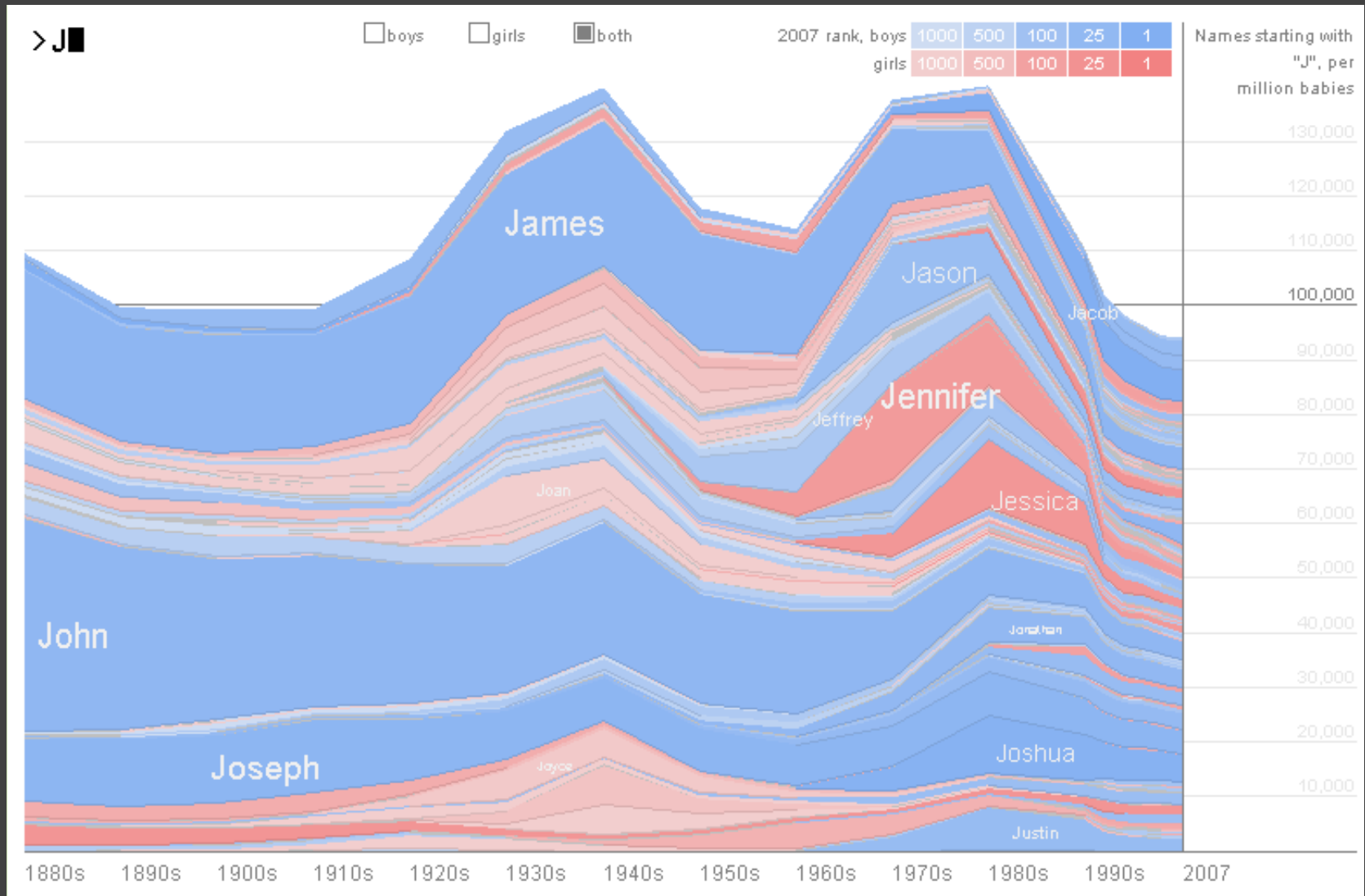


Hit the letter **z**, or click the word **zoom** to enable or disable zooming.

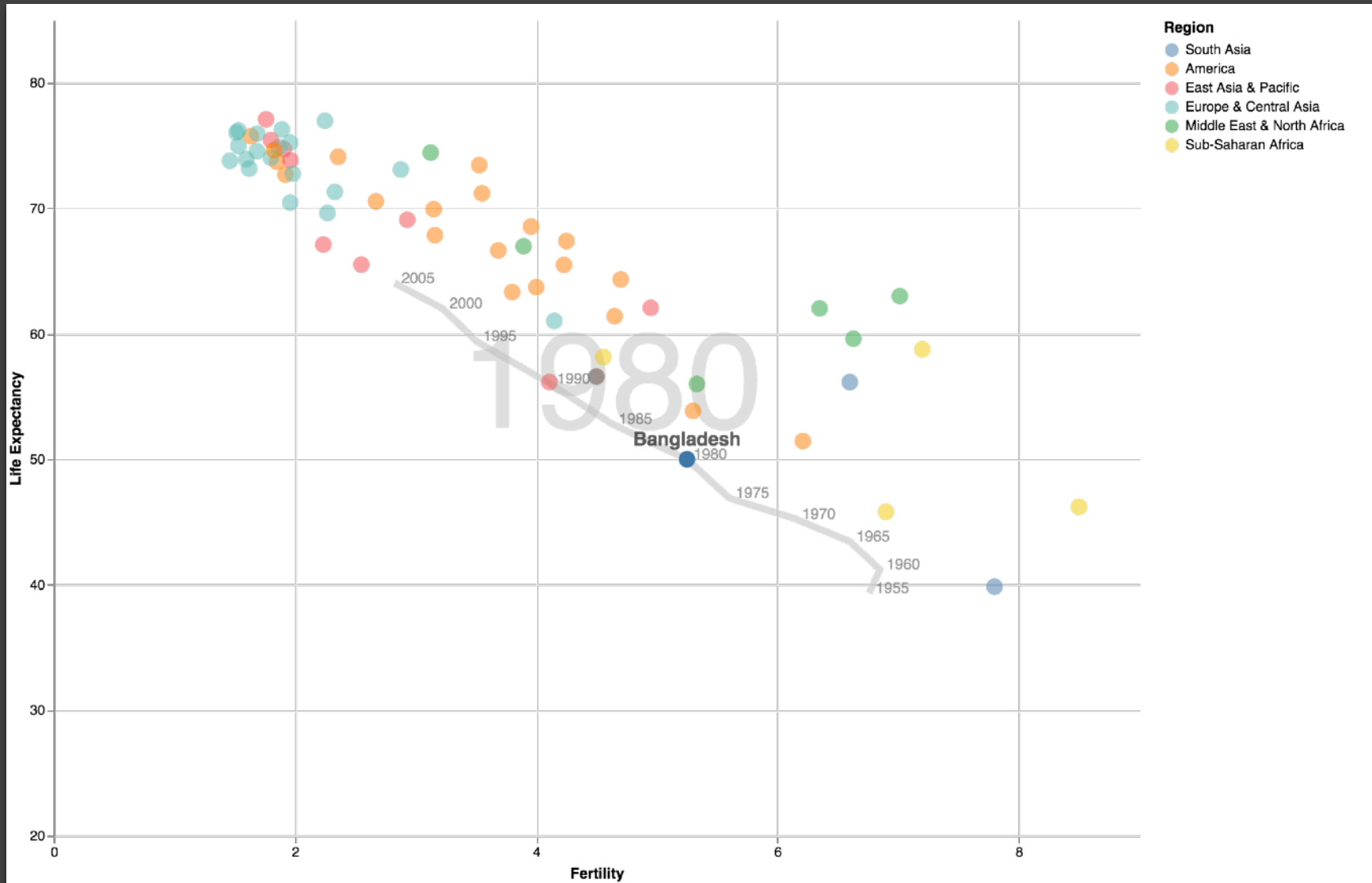
Hold down **shift** while typing a number to replace the previous number (U.S. keyboards only).

<http://benfry.com/zipdecode/>

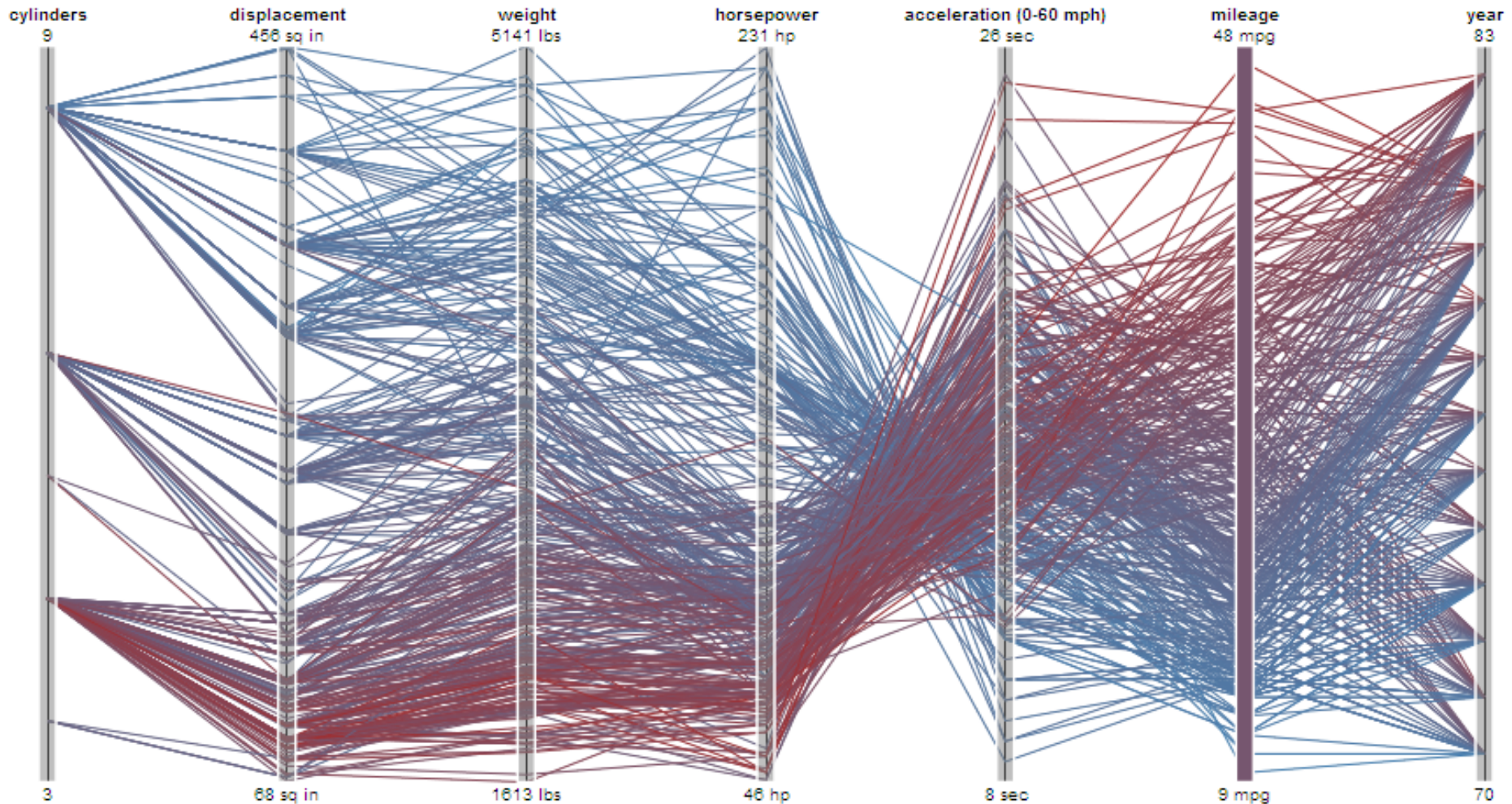
# NameVoyager [Wattenberg 06]



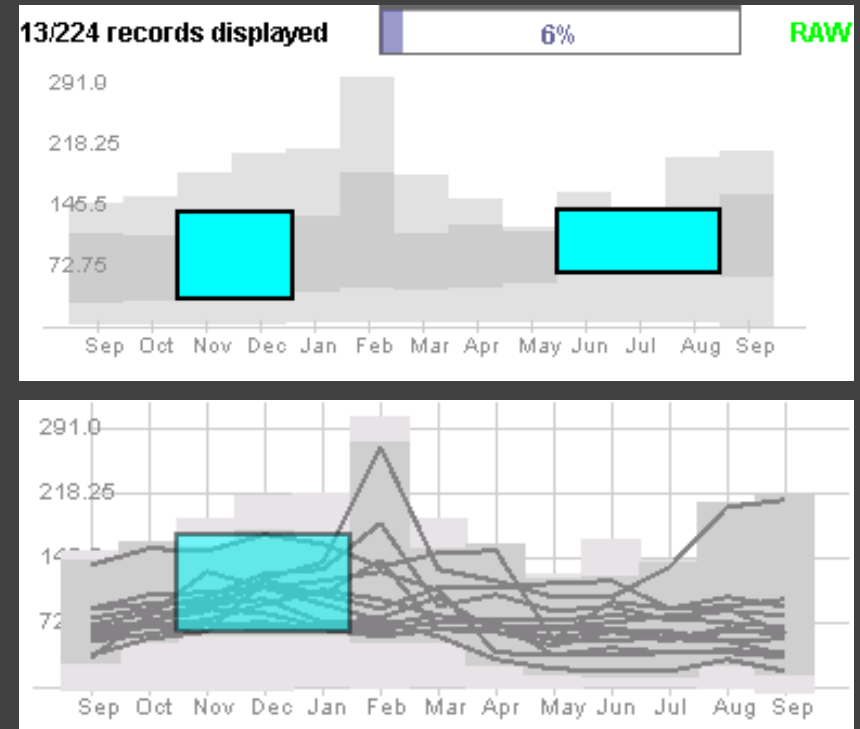
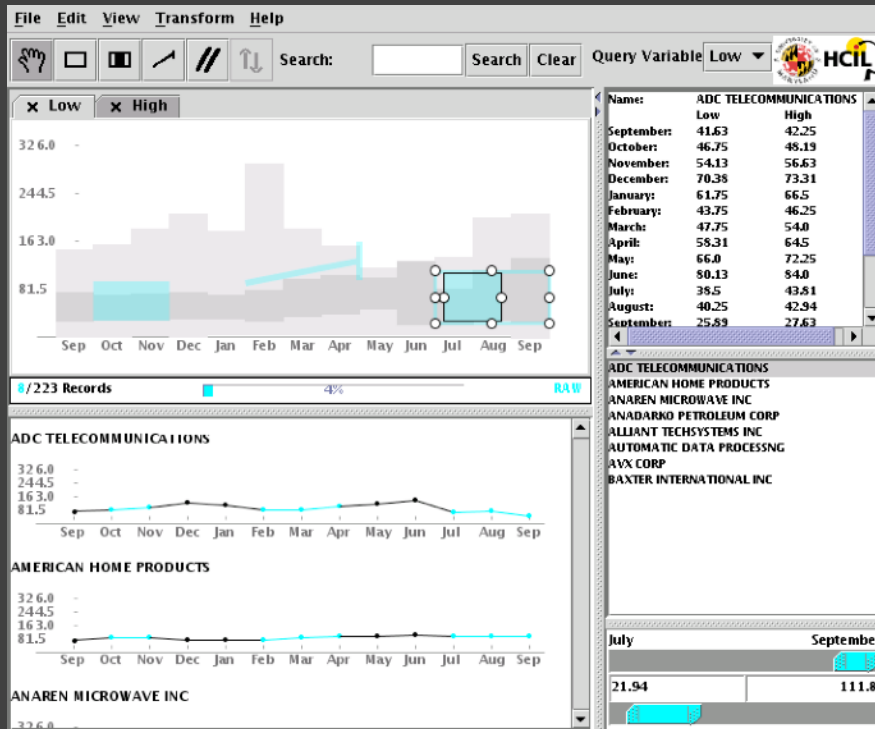
# DimpVis [Kondo 14]



# Parallel Coordinates [Inselberg]



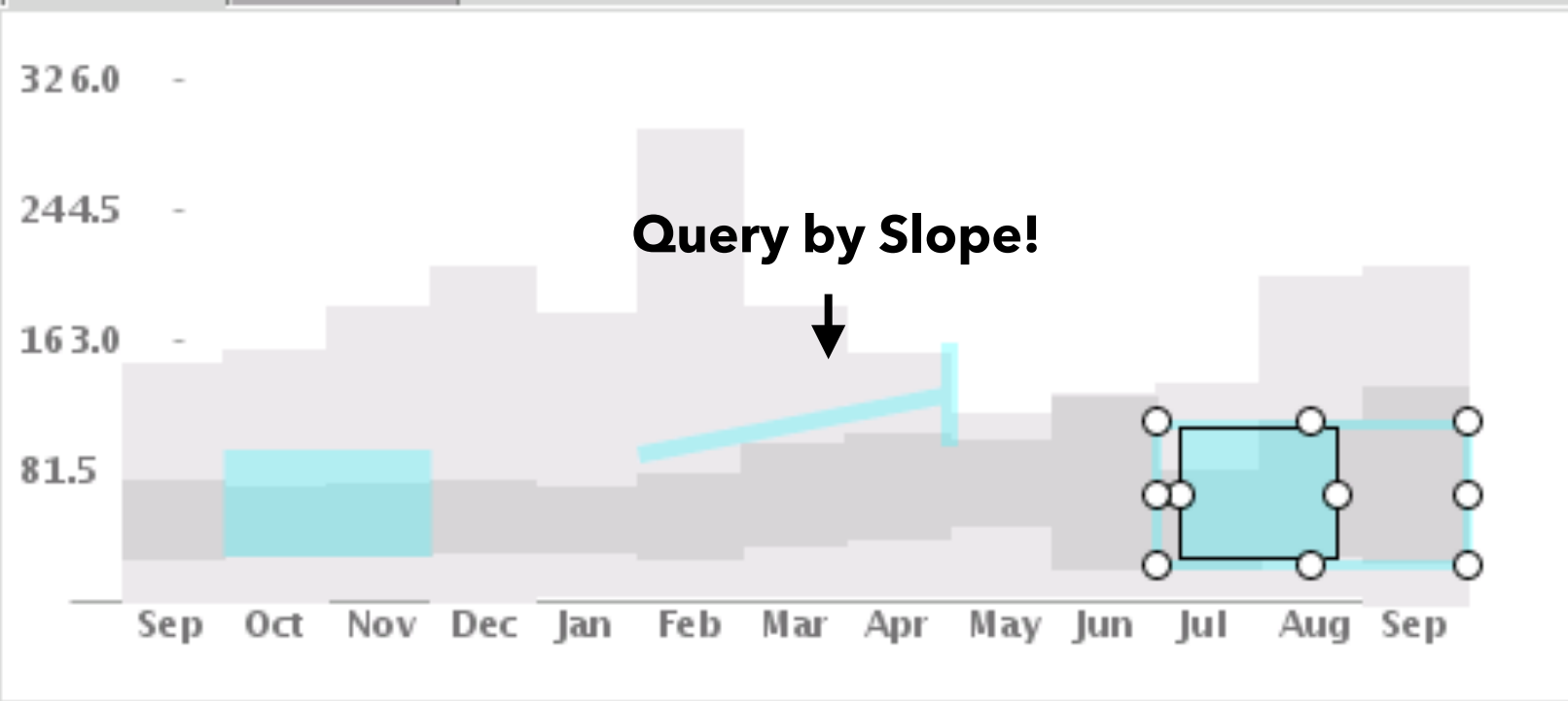
# TimeSearcher [Hocheiser 02]



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

X Low

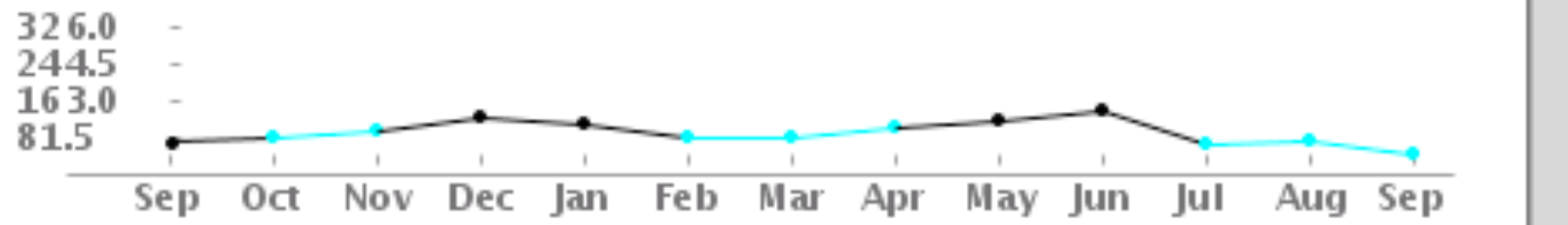
X High



- Name:
- September:
- October:
- November:
- December:
- January:
- February:
- March:
- April:
- May:
- June:
- July:
- August:
- September:

8/223 Records ■ 4% RAW

**ADC TELECOMMUNICATIONS**



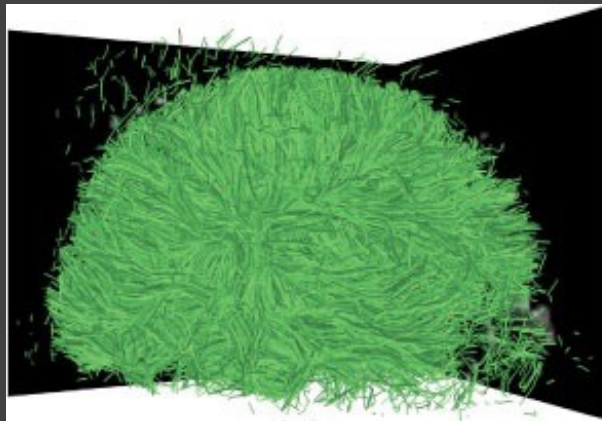
**AMERICAN HOME PRODUCTS**



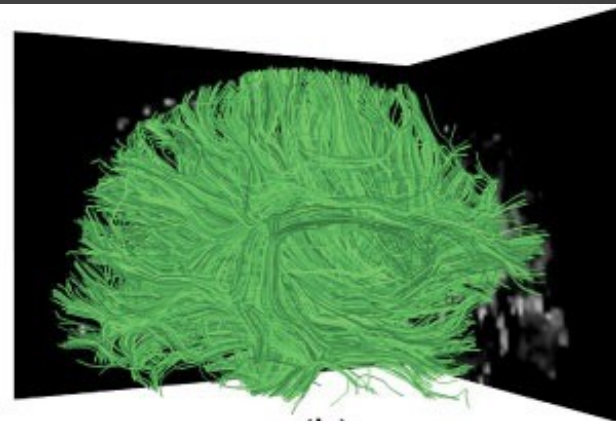
- ADC TELECOMM
- AMERICAN HOM
- ANAREN MICRO
- ANADARKO PET
- ALLIANT TECHS
- AUTOMATIC DA
- AVX CORP
- BAXTER INTERN



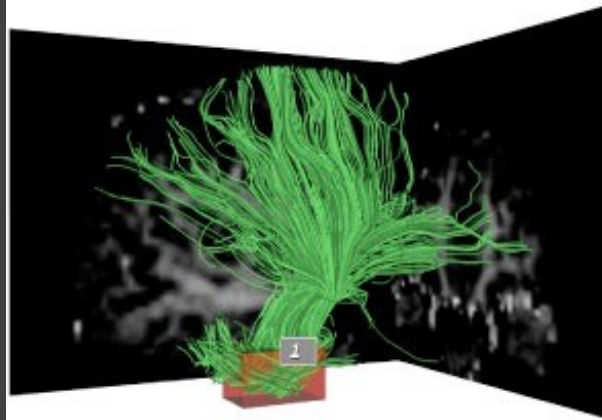
# 3D Dynamic Queries [Akers 04]



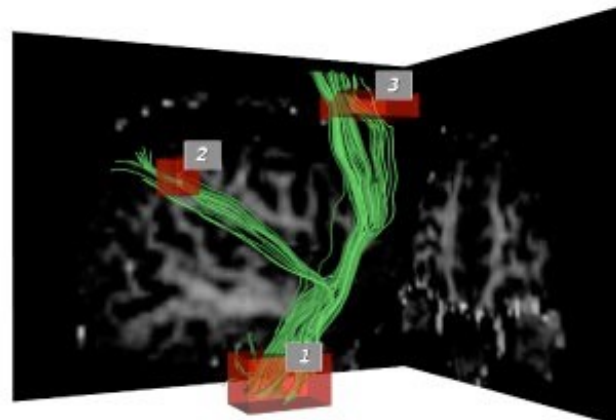
(a)



(b)

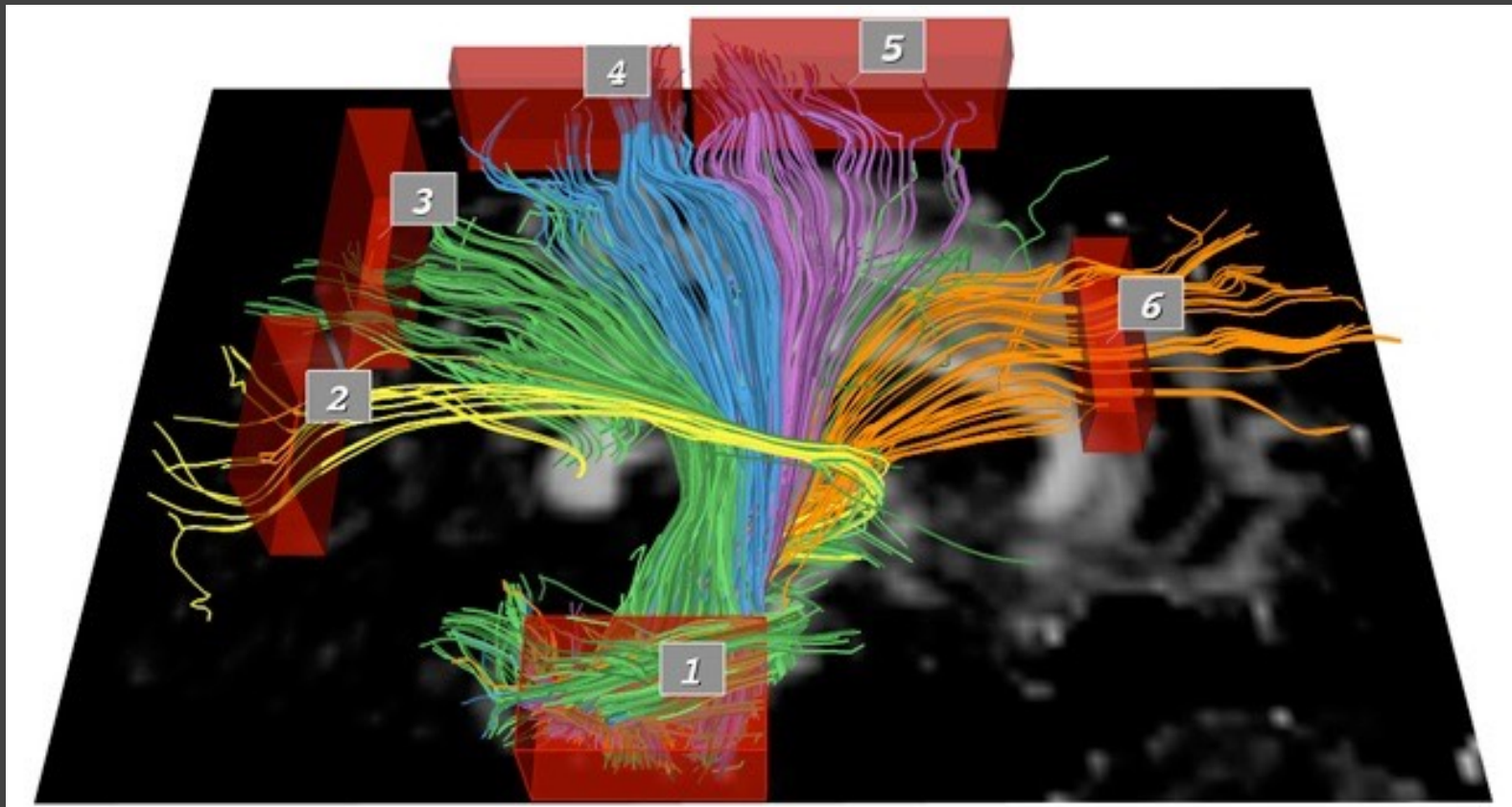


(c)



(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

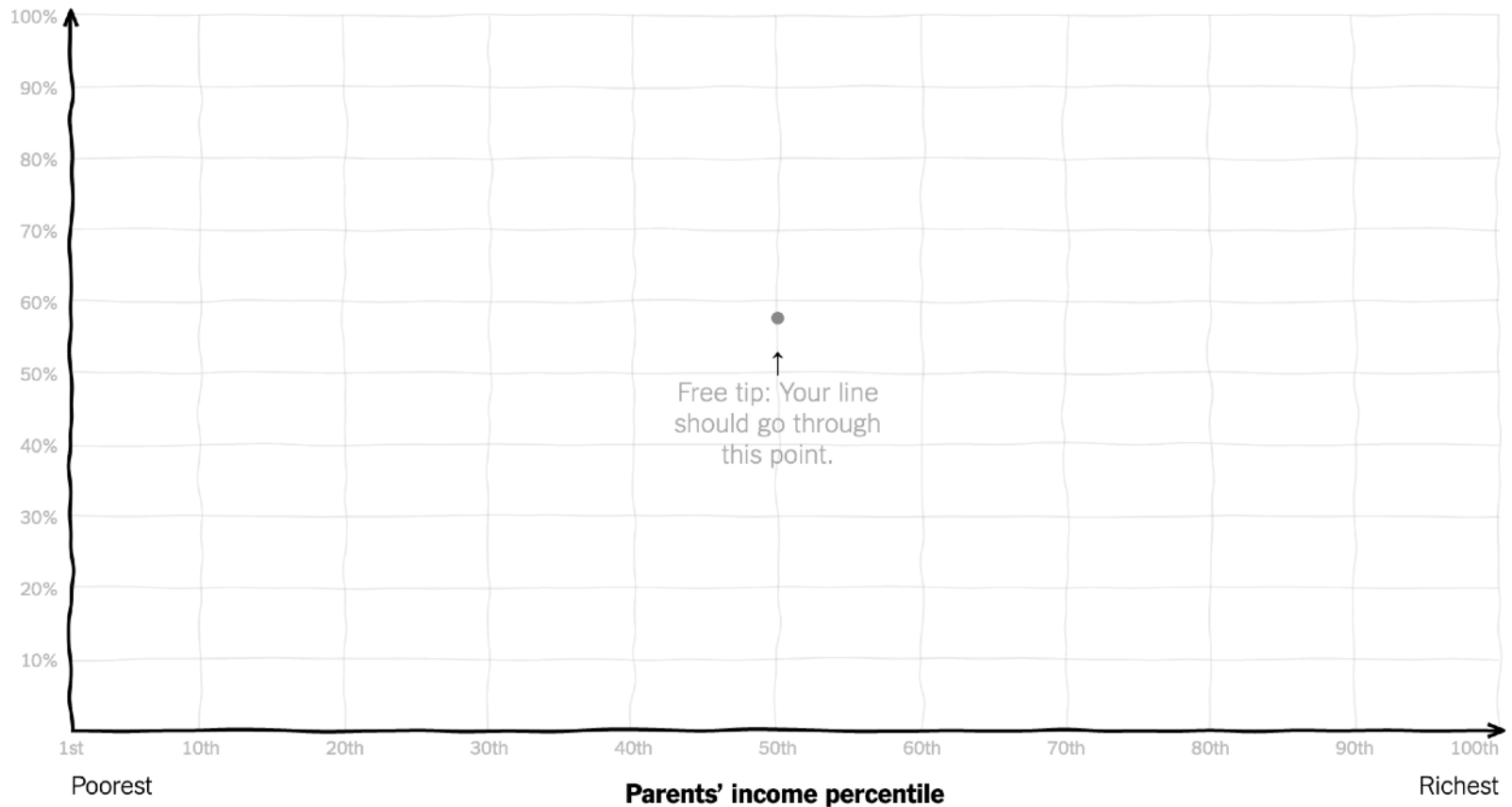
Simple queries  
Lots of controls  
Amount of data shown limited by screen space  
Who would use these kinds of tools?

# Prompting Reflection

# You Draw It [Aisch et al. '15]

**Draw your line on the chart below**

**Percent of children who attended college**



# 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 10/16 11:59pm.**

# A2 Peer Reviews

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 **Tue 10/22 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."*

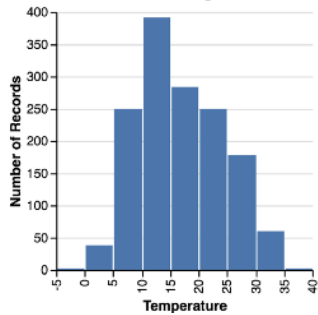
## **WHAT IF?**

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?"*

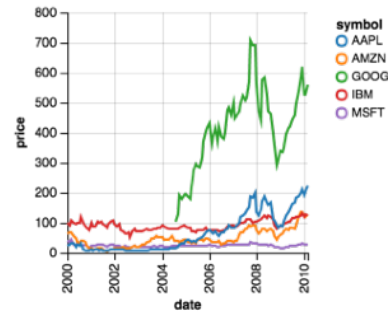
# An Interaction Grammar (Vega-Lite Selections)

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

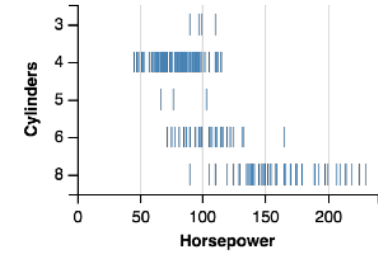
### Histogram



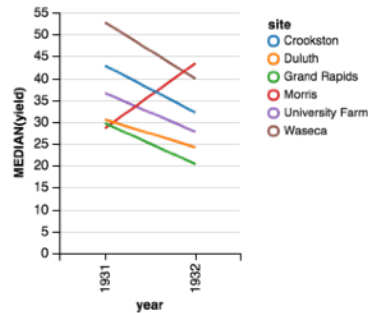
### Line Chart



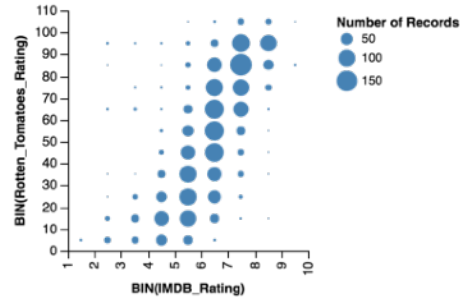
### Strip Plot



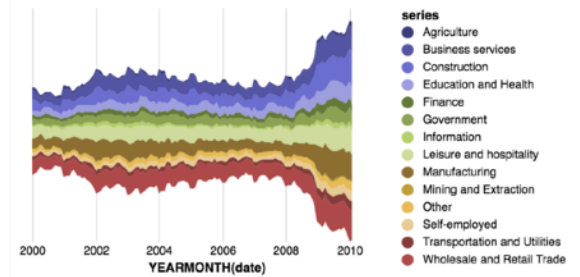
### Slope Graph



### Binned Scatter Plot

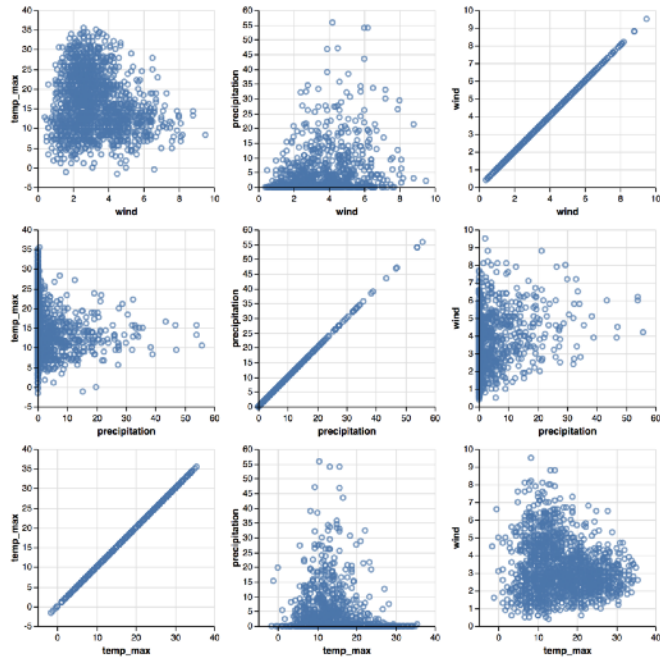


### Area Chart

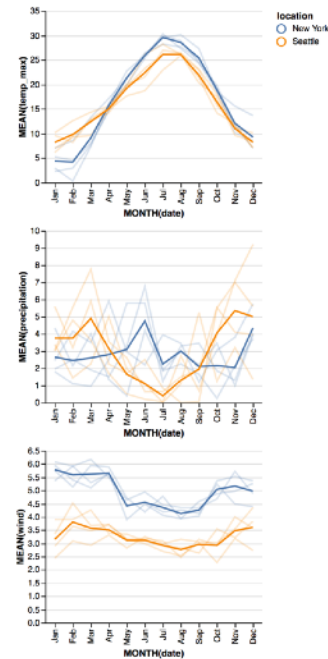


# Vega-Lite: A Grammar of Graphics

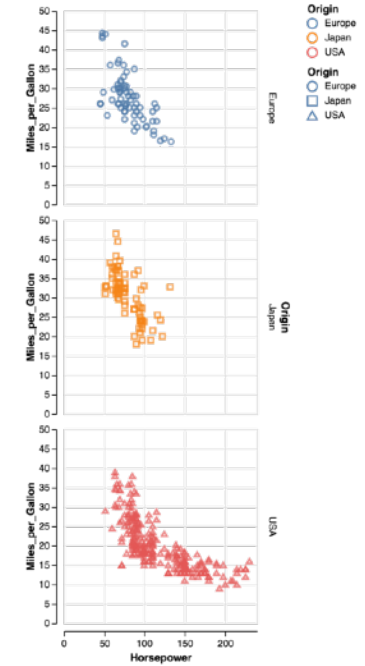
## Scatter Plot Matrix



## Concat & Layered Views

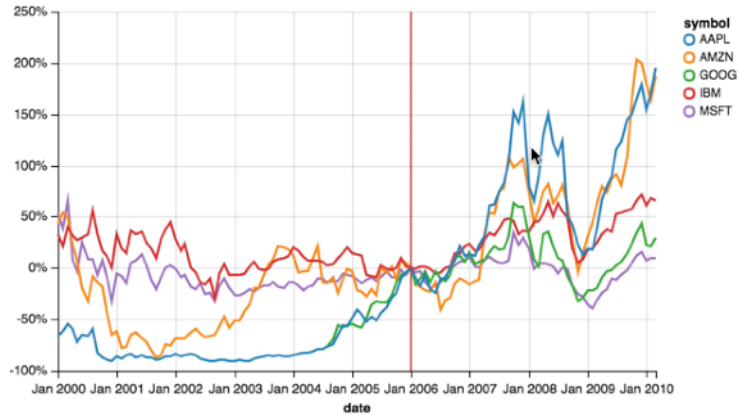


## Faceted Views

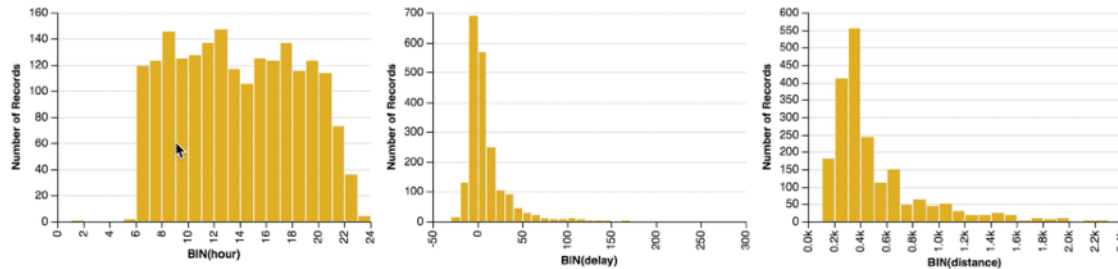
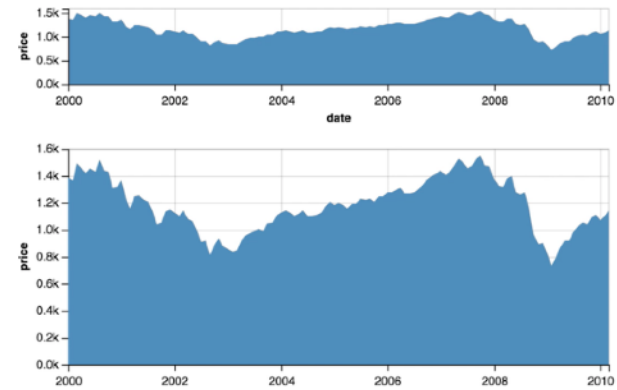


# Vega-Lite: A Grammar of **Multi-View** Graphics

## Indexed Chart



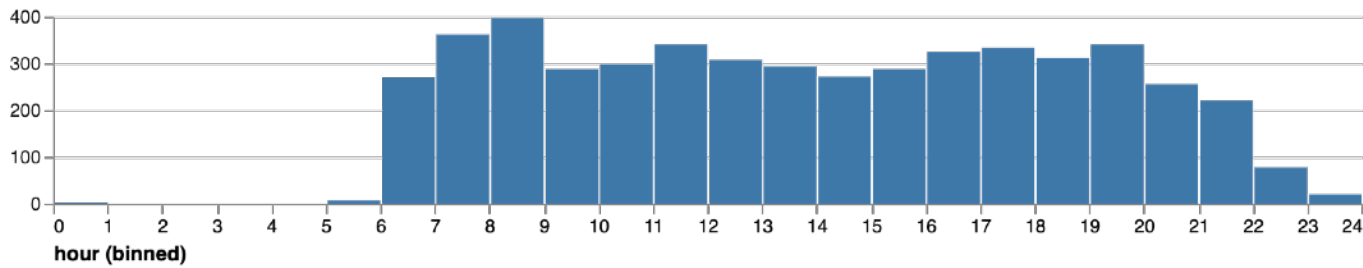
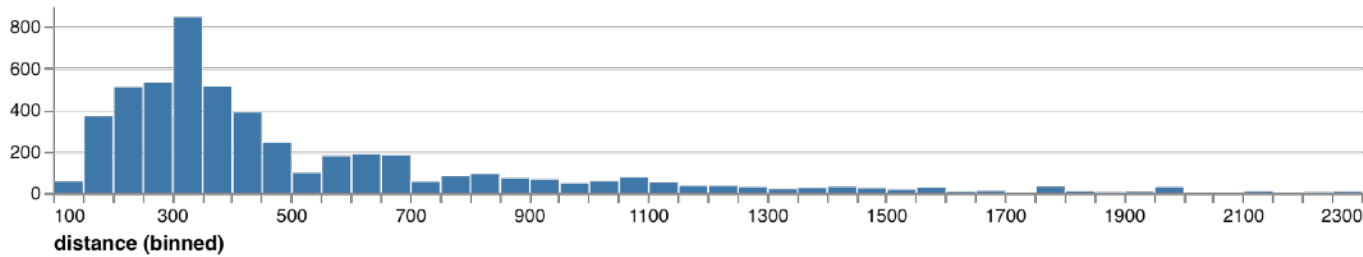
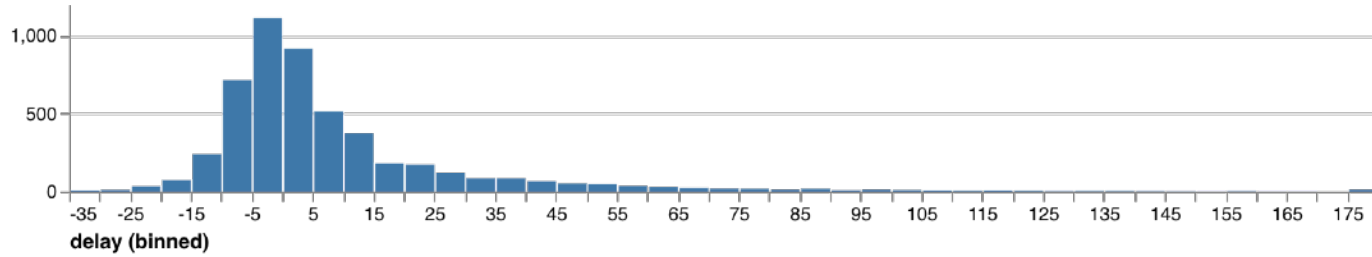
## Focus + Context



## Cross-Filtering

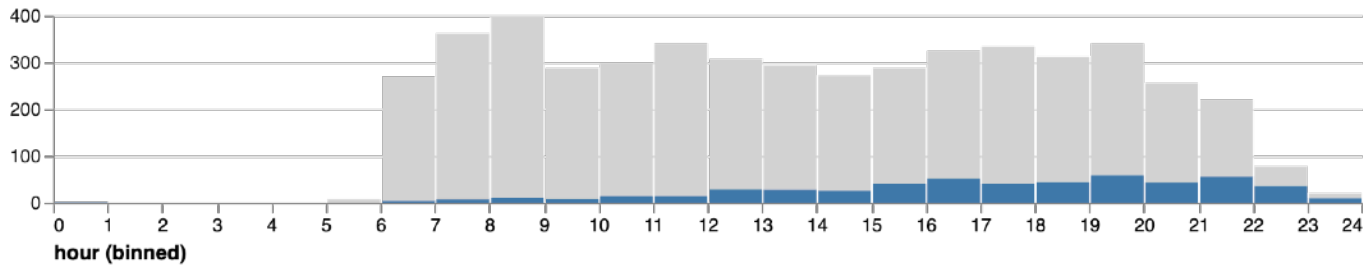
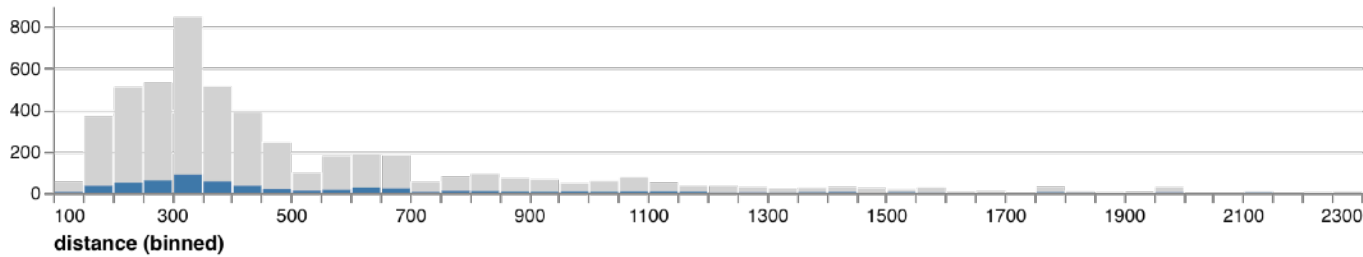
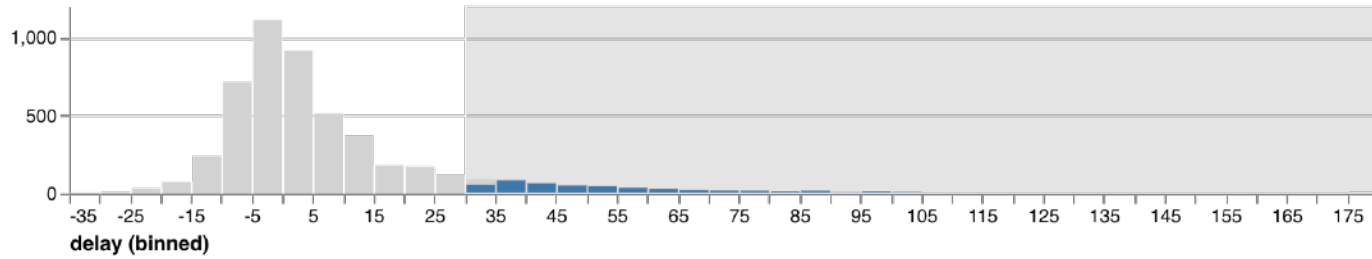
Vega-Lite: A Grammar of **Interactive** Graphics

# Cross-Filtering in Vega-Lite



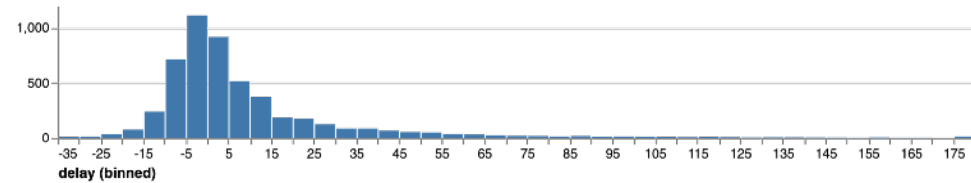


# Cross-Filtering in Vega-Lite



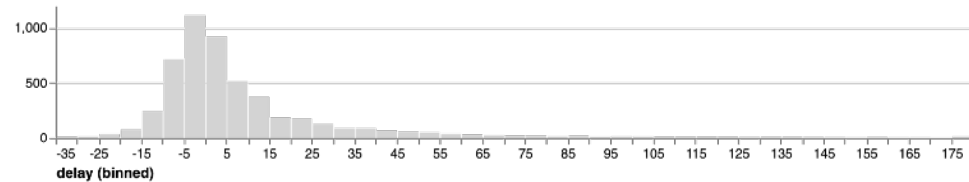
# Cross-Filtering in Vega-Lite

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



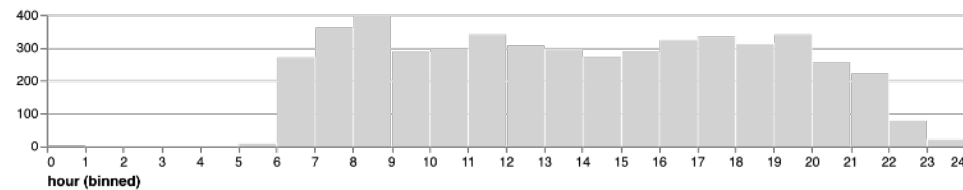
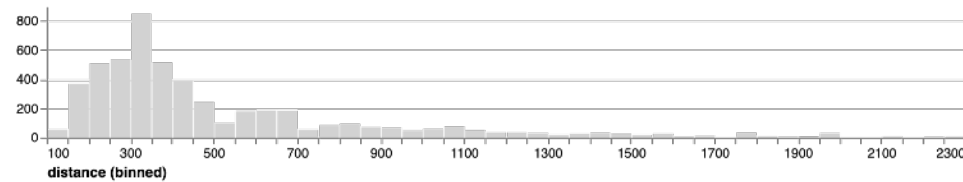
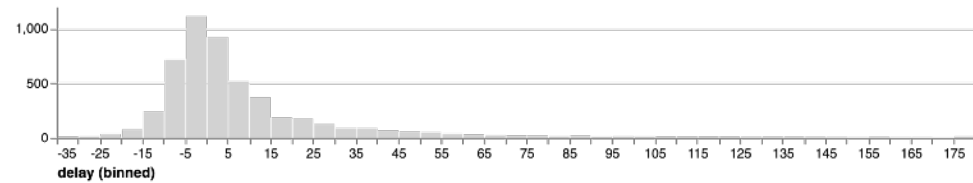
# Cross-Filtering in Vega-Lite

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



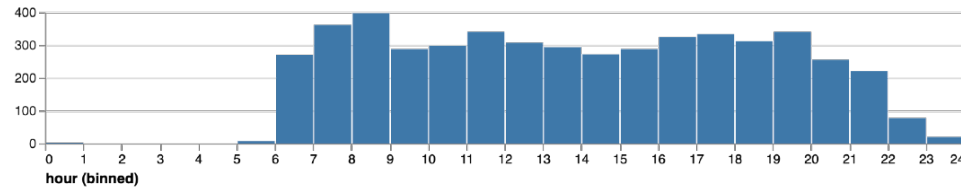
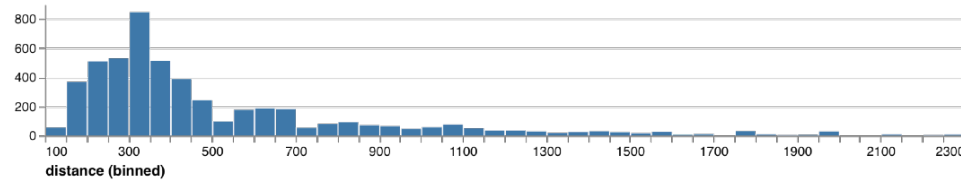
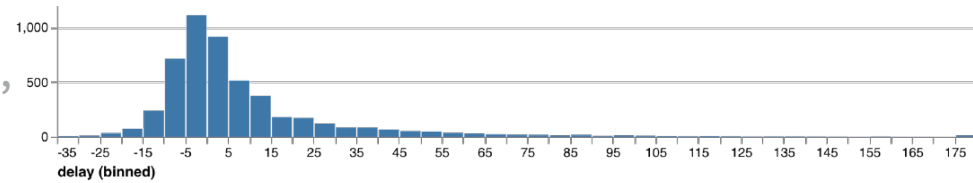
# Cross-Filtering in Vega-Lite

```
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

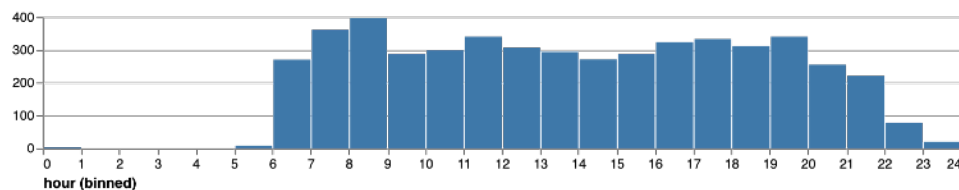
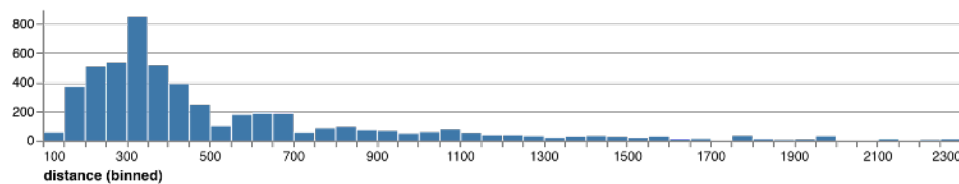
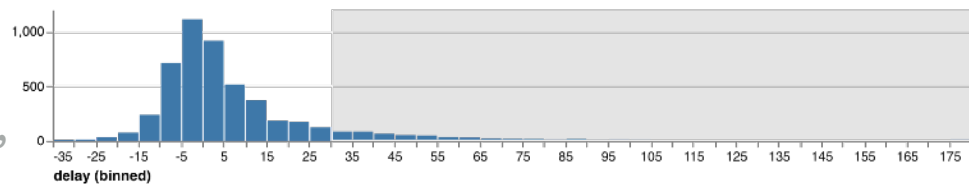
```
layer(  
  markBar().encode(  
    x().fieldQ(repeat('row')).bin(true),  
    y().count(),  
    color().value('lightgrey')  
  ),  
  markBar().encode(  
    x().fieldQ(repeat('row')).bin(true),  
    y().count()  
  )  
).repeat({  
  row: ['delay', 'distance', 'hour']  
})  
.data('data/flights.json')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



# Cross-Filtering in Vega-Lite

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

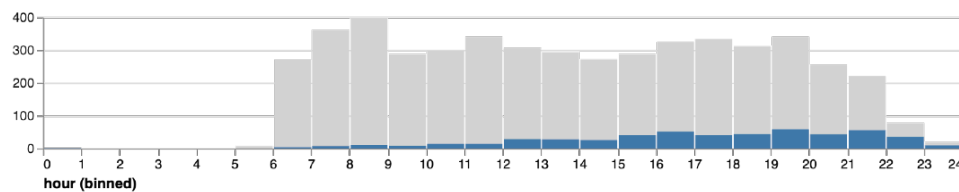
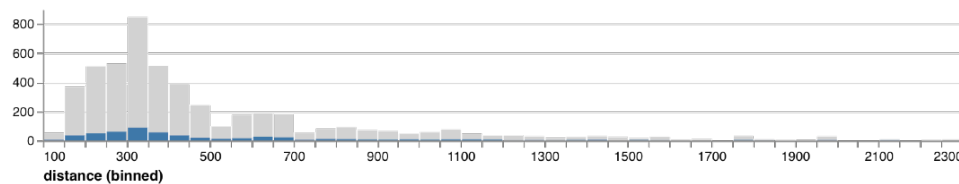
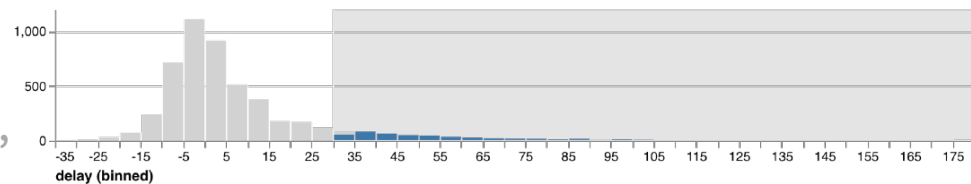
```
layer(  
  markBar().encode(  
    x().fieldQ(repeat('row')).bin(true),  
    y().count(),  
    color().value('lightgrey')  
  ).params(brush),  
  markBar().encode(  
    x().fieldQ(repeat('row')).bin(true),  
    y().count()  
  )  
)  
.repeat({  
  row: ['delay', 'distance', 'hour']  
})  
.data('data/flights.json')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



# Cross-Filtering in Vega-Lite

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

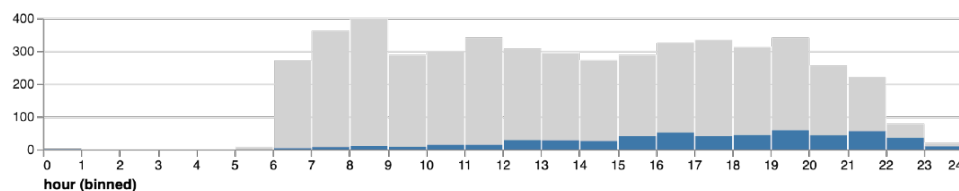
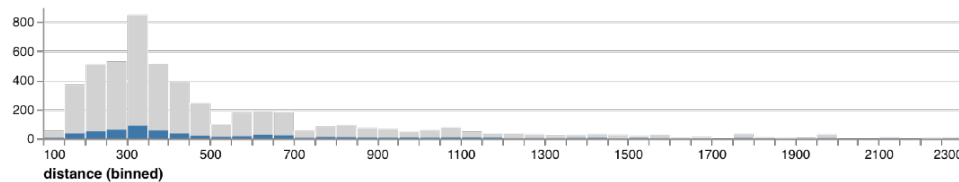
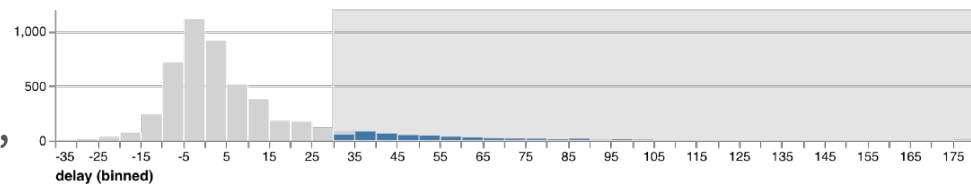
```
layer(  
  markBar().encode(  
    x().fieldQ(repeat('row')).bin(true),  
    y().count(),  
    color().value('lightgrey')  
  ).params(brush),  
  markBar().encode(  
    x().fieldQ(repeat('row')).bin(true),  
    y().count()  
  ).transform(filter(brush))  
)  
.repeat({  
  row: ['delay', 'distance',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

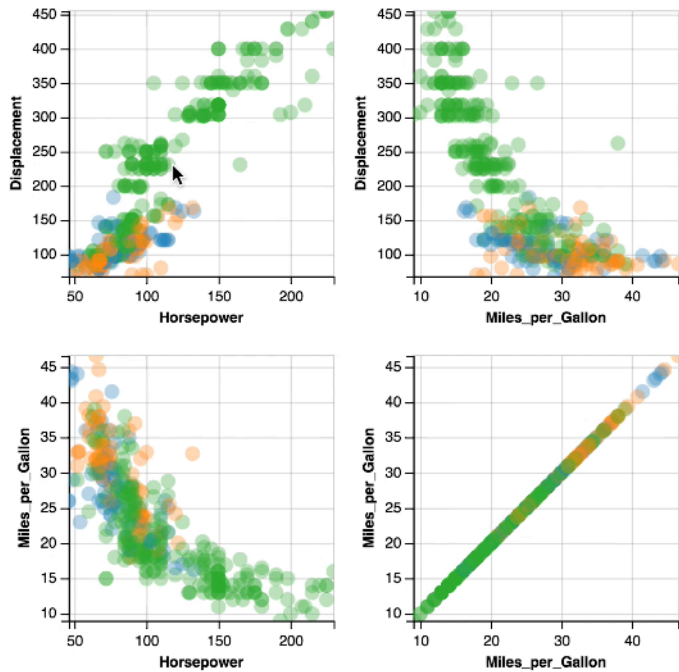
**Scale inversion:** visual space → data space

**Predicate:** test if a data record is selected

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

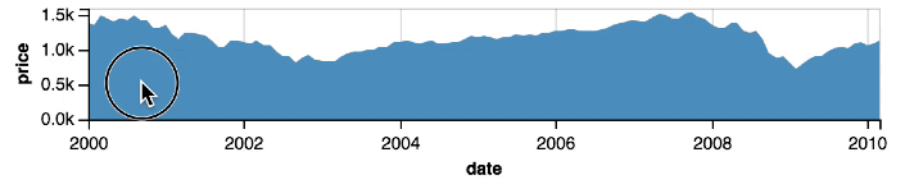
# Selections

Selections *invert* scales and *parameterize* graphics

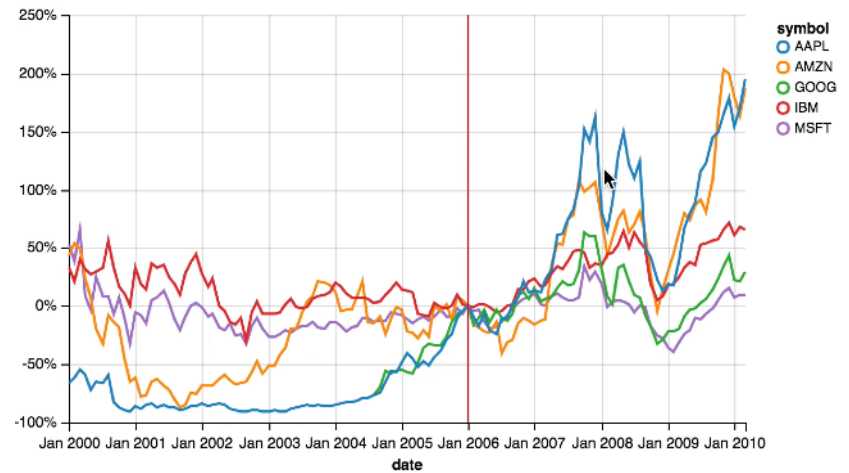
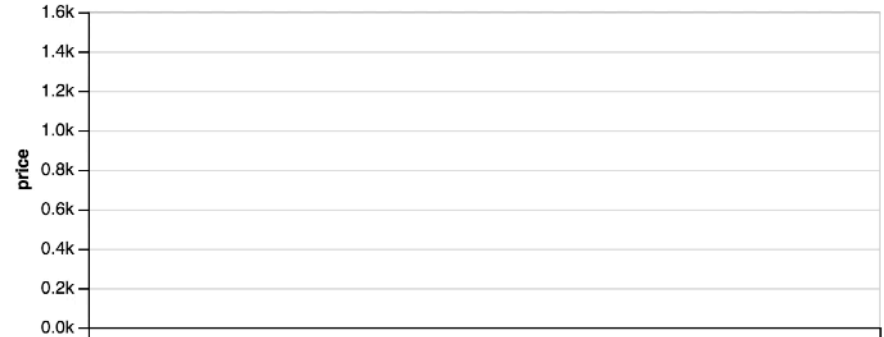


Bind selection to scale domains:  
*Synchronized Pan & Zoom!*

## Overview + Detail



Origin  
● Europe  
● Japan  
● USA



*Parameterized Transformations*