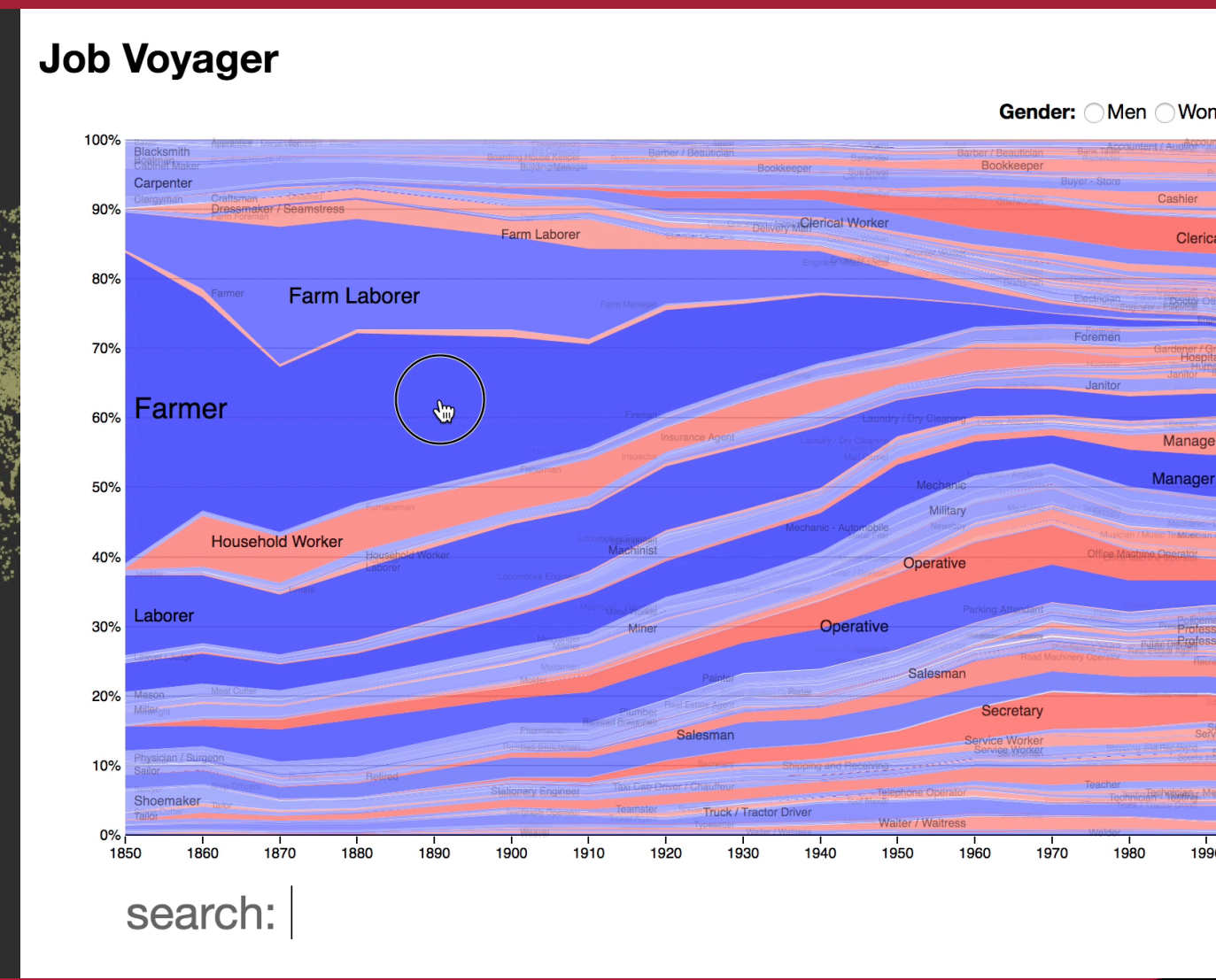
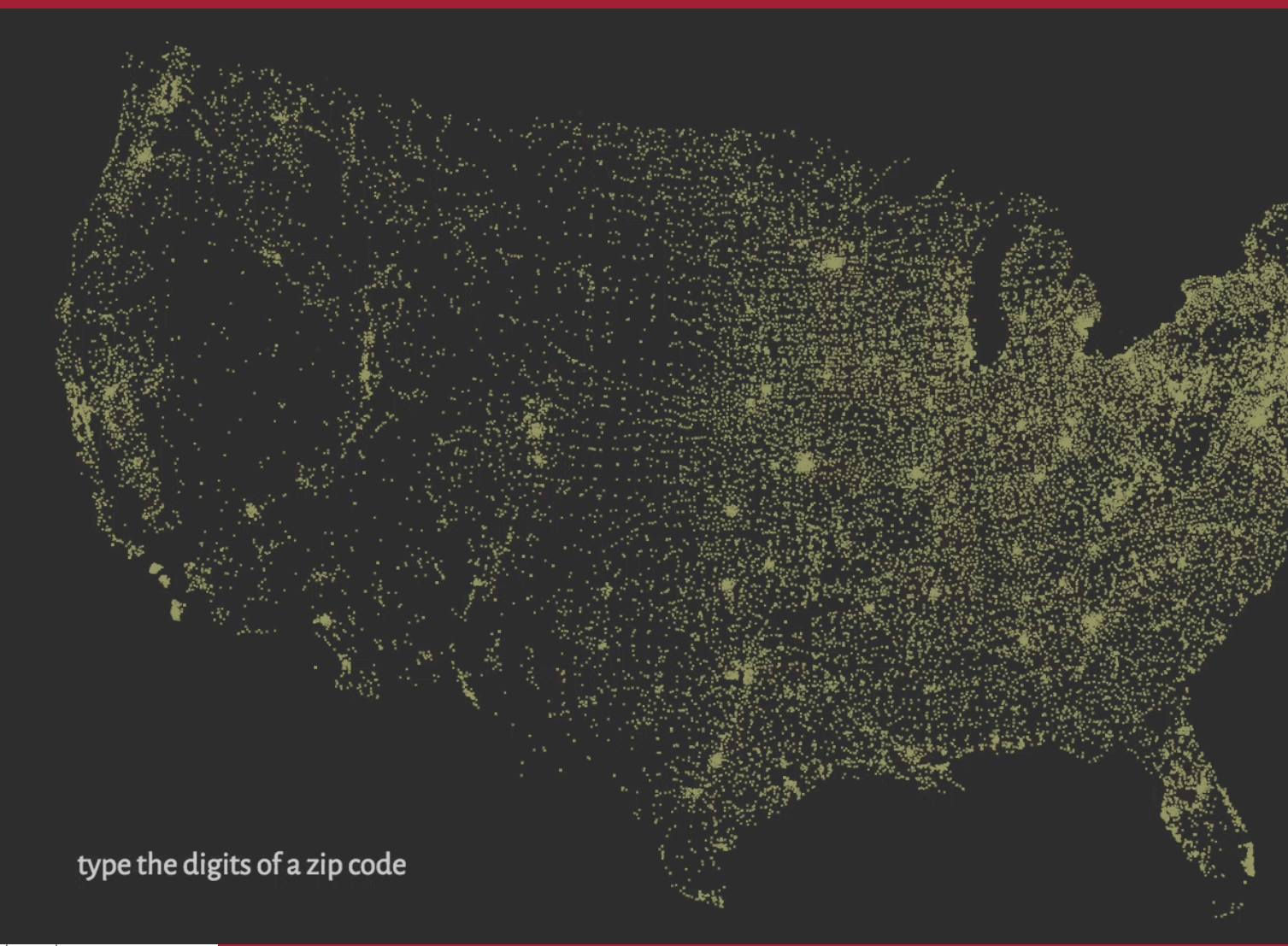
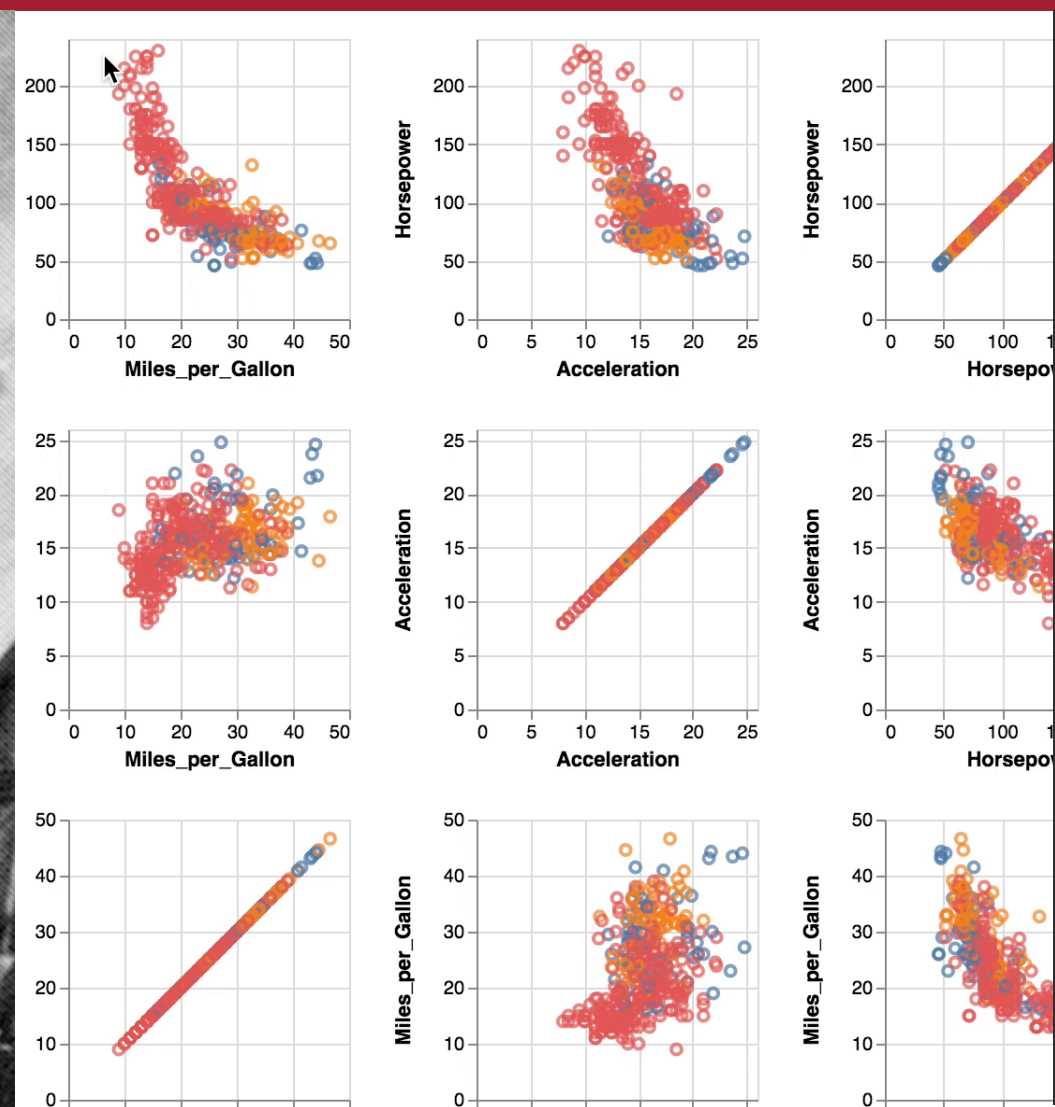


# 6.859: Interactive Data Visualization

## A Tour through the Interaction Zoo

Arvind Satyanarayan







*A graphic is not “drawn” once and for all; it is “constructed” and reconstructed until it reveals all the relationships constituted by the interplay of the data. The best graphic operations are those carried out by the decision-maker [themselves].*

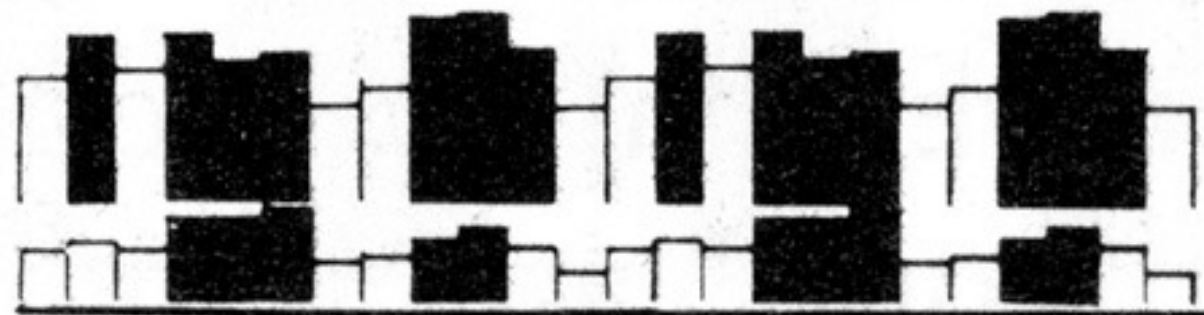
Jacques Bertin (1918 – 2010)  
French cartographer



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



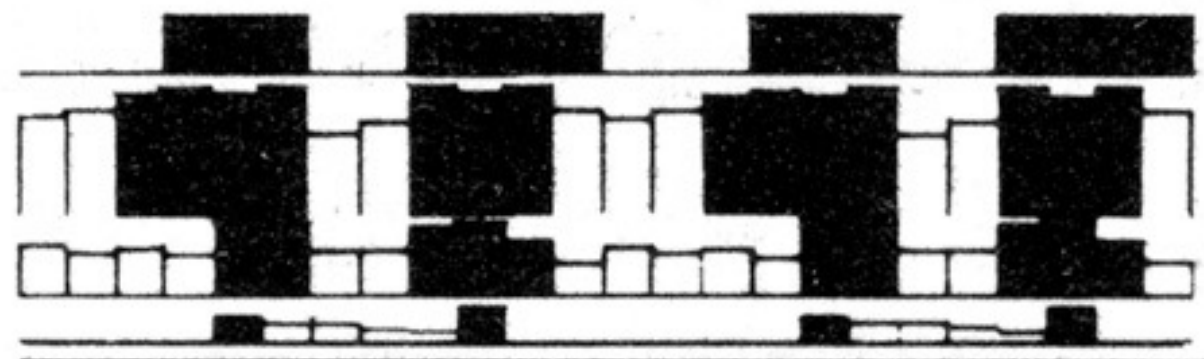
J F M A M J J A S O N D J F M A M J J A S O N D



18 % OCCUPANCY

18 LENGTH OF STAY

*ACTIVE AND SLOW PERIODS*



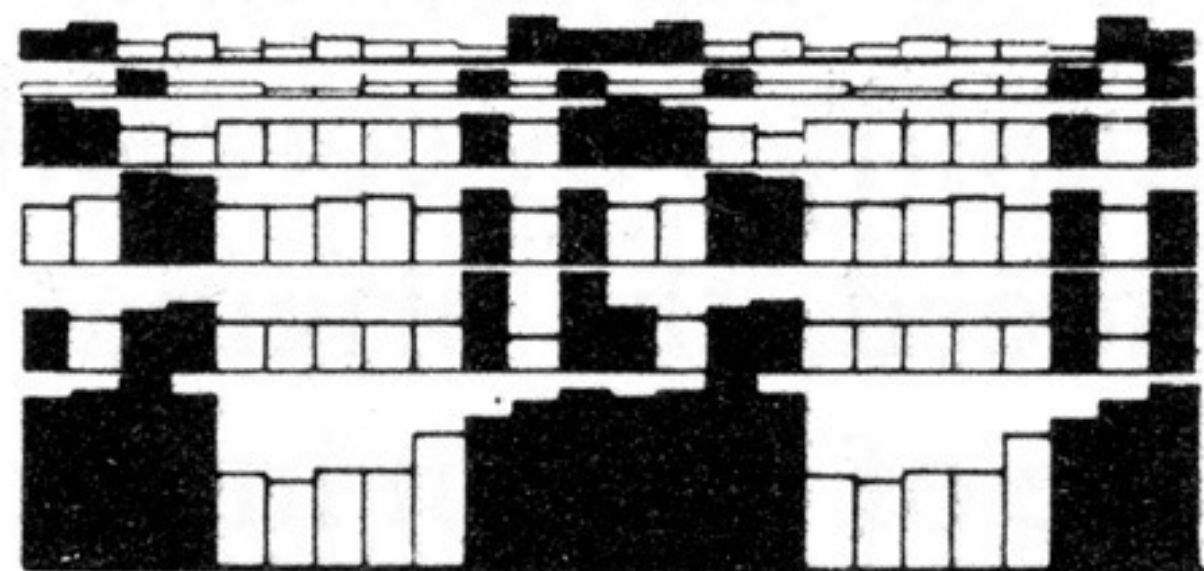
20 CONVENTIONS

8 BUSINESSMEN

11 AGENCY RESERVATIONS

4 SOUTH AMERICA

*DISCOVERY FACTORS*



18 AIR CREWS

18 CLIENTS UNDER 20 YEARS

18 CLIENTS MORE THAN 55 YEARS

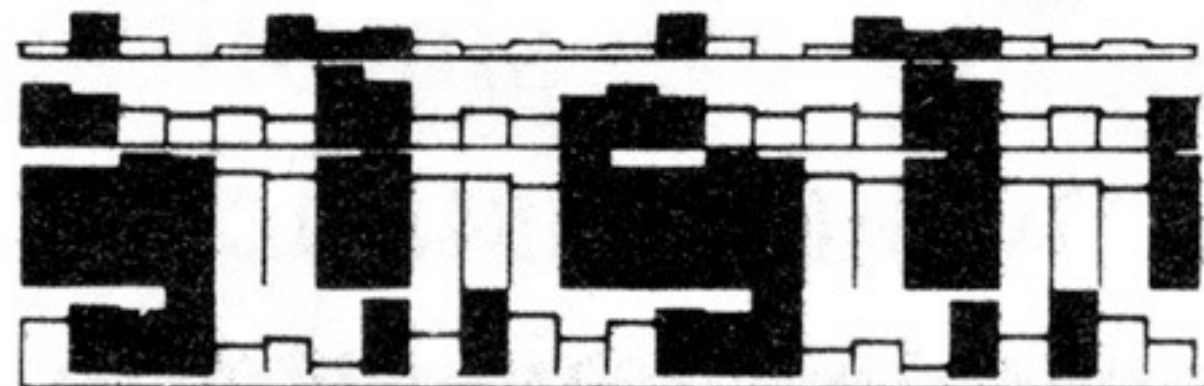
14 CLIENTS FROM 20-35 YEARS

1 FEMALE CLIENTELE

2 LOCAL CLIENTELE

*RECOVERY FACTORS*

*WINTER*



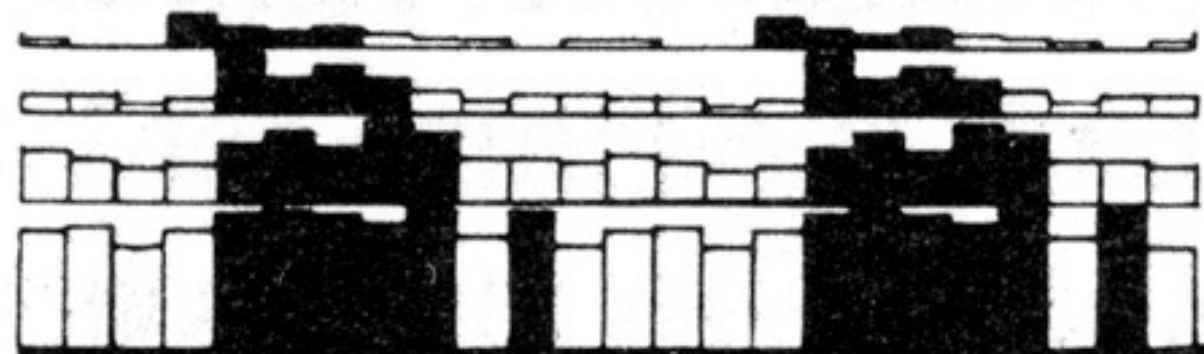
7 ASIA

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

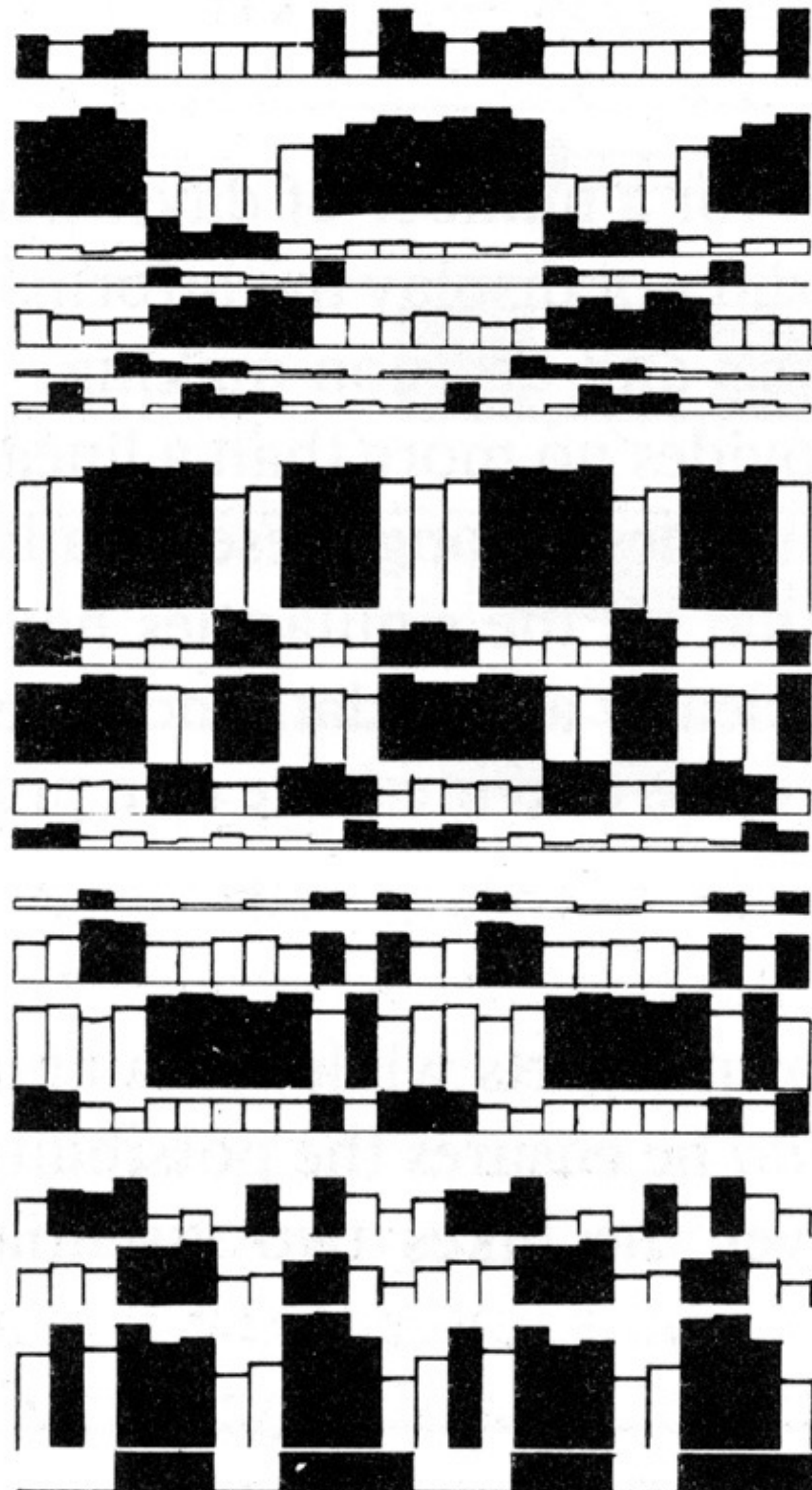
*SUMMER*



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



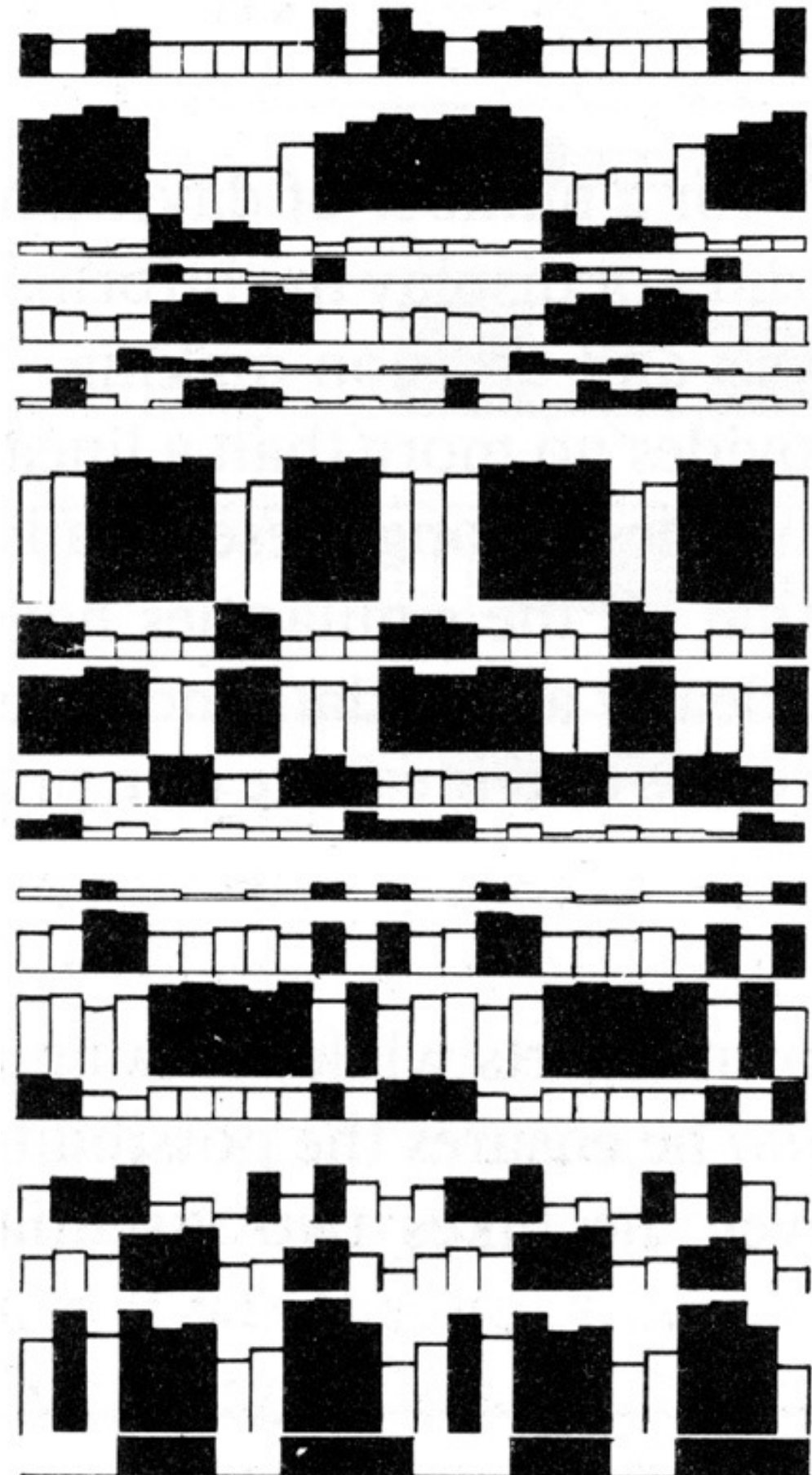
J F M A M J J A S O N D J F M A M J J A S O N D



1	% CLIENTELE FEMALE
2	% —"—— LOCAL
3	% —"—— U.S.A.
4	% —"—— SOUTH AMERICA
5	% —"—— EUROPE
6	% —"—— M.EAST, AFRICA
7	% —"—— ASIA
8	% BUSINESSMEN
9	% TOURISTS
10	% DIRECT RESERVATIONS
11	% AGENCY ———"——
12	% AIR CREWS
13	% CLIENTS UNDER 20 YEARS
14	% —"—— 20-35 —"——
15	% —"—— 35-55 —"——
16	% —"—— MORE THAN 55 —"——
17	PRICE OF ROOMS
18	LENGTH OF STAY
19	<b>% OCCUPANCY</b>
20	<b>CONVENTIONS</b>

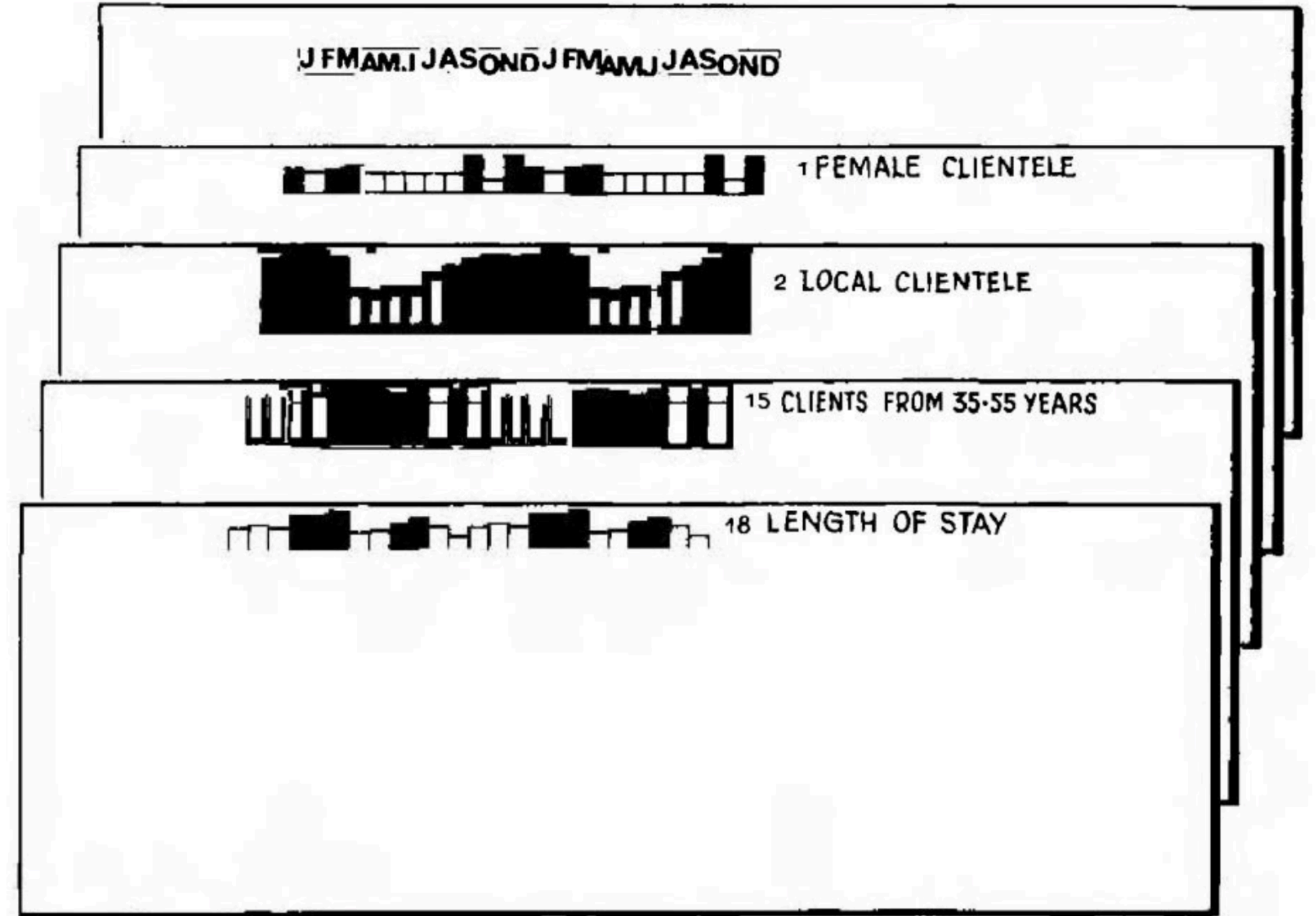


J FMAMJ JASONDJ FMAMJ JASONDJ

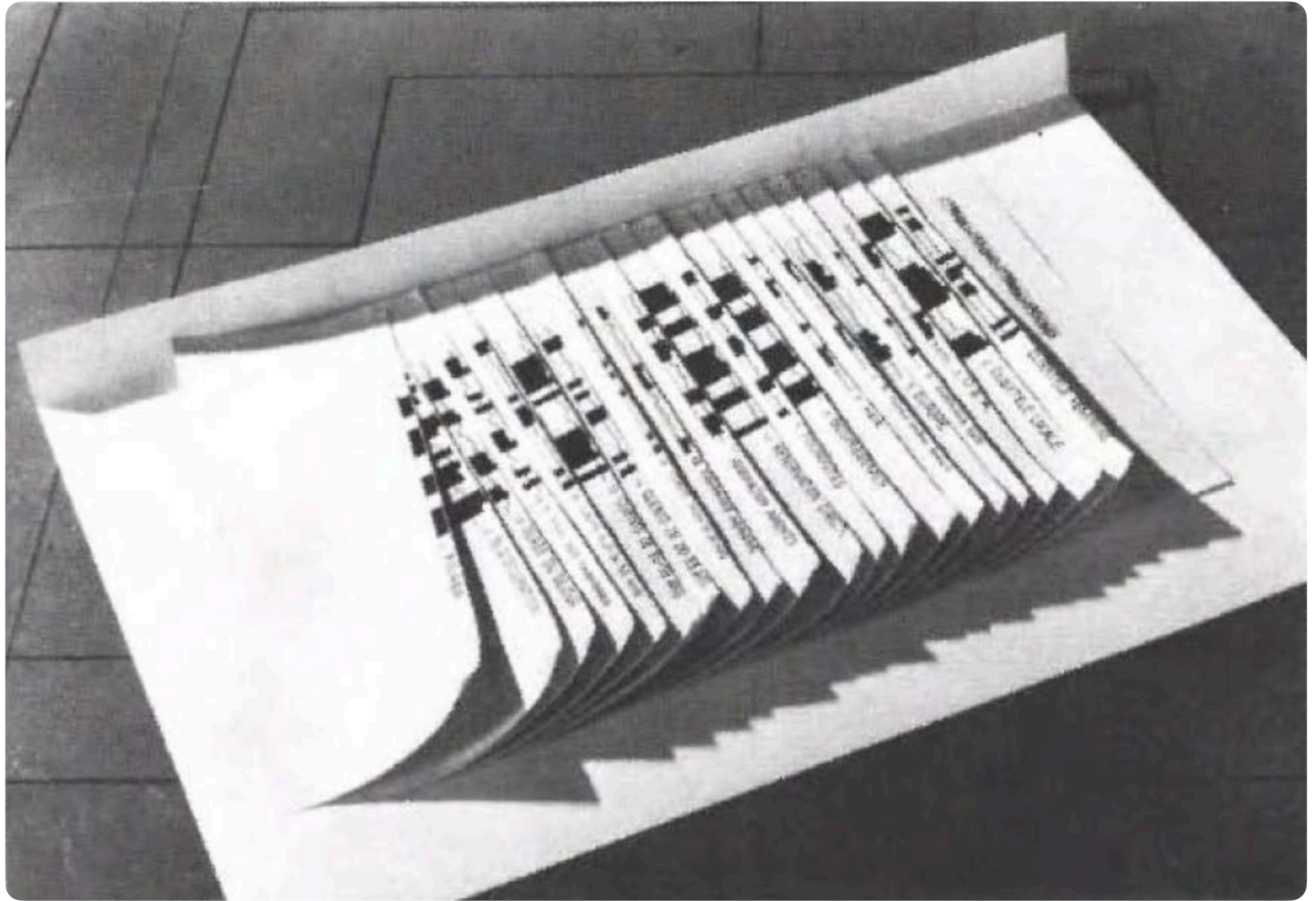
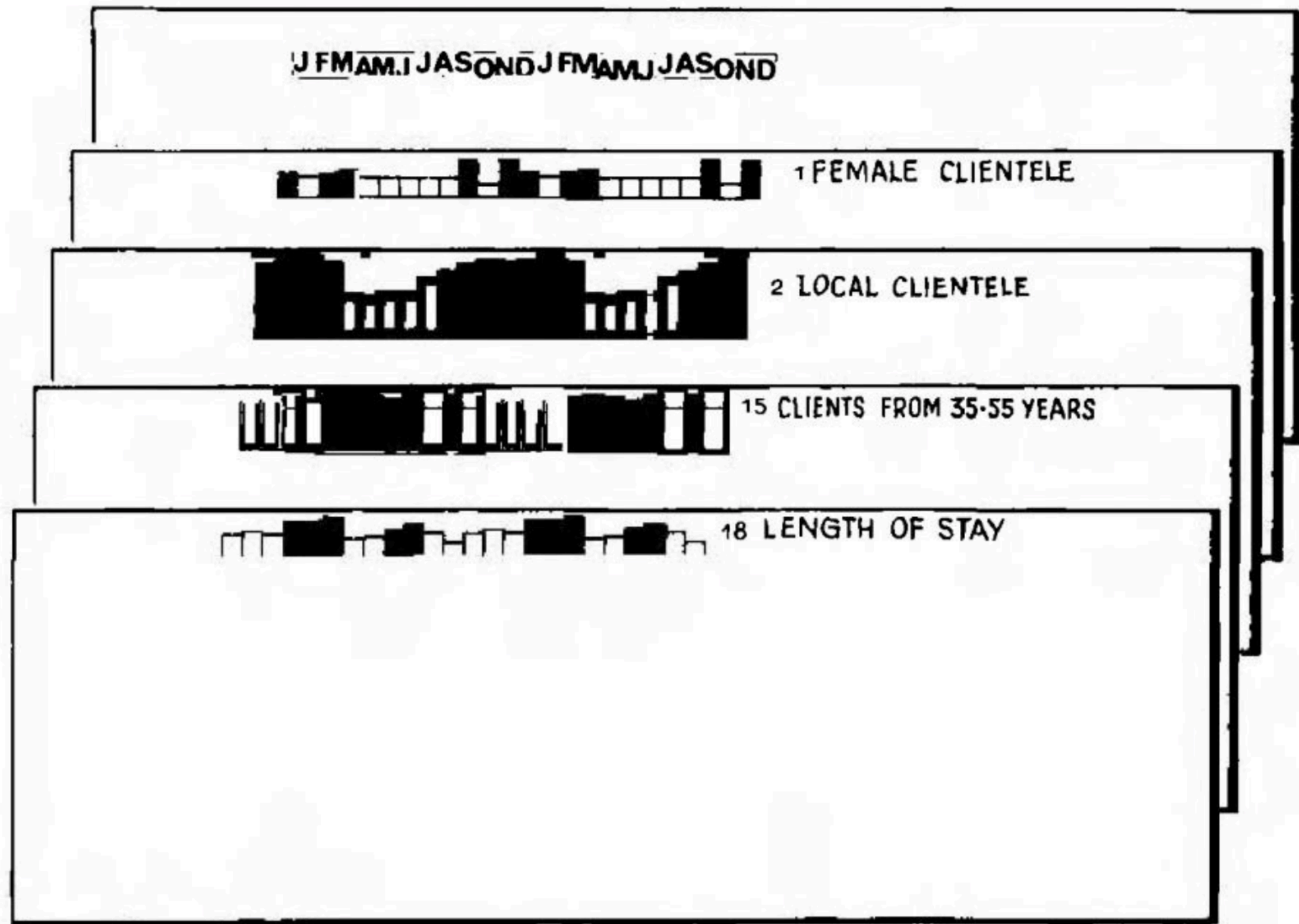


1	% CLIENTELE FEMALE
2	% —//— LOCAL
3	% —//— U.S.A.
4	% —//— SOUTH AMERICA
5	% —//— EUROPE
6	% —//— M.EAST, AFRICA
7	% —//— ASIA
8	% BUSINESSMEN
9	% TOURISTS
10	% DIRECT RESERVATIONS
11	% AGENCY —//—
12	% AIR CREWS
13	% CLIENTS UNDER 20 YEARS
14	% —//— 20-35 —//—
15	% —//— 35-55 —//—
16	% —//— MORE THAN 55 —//—
17	PRICE OF ROOMS
18	LENGTH OF STAY
19	% OCCUPANCY
20	CONVENTIONS

J FMAMJ JASONDJ FMAMJ JASONDJ



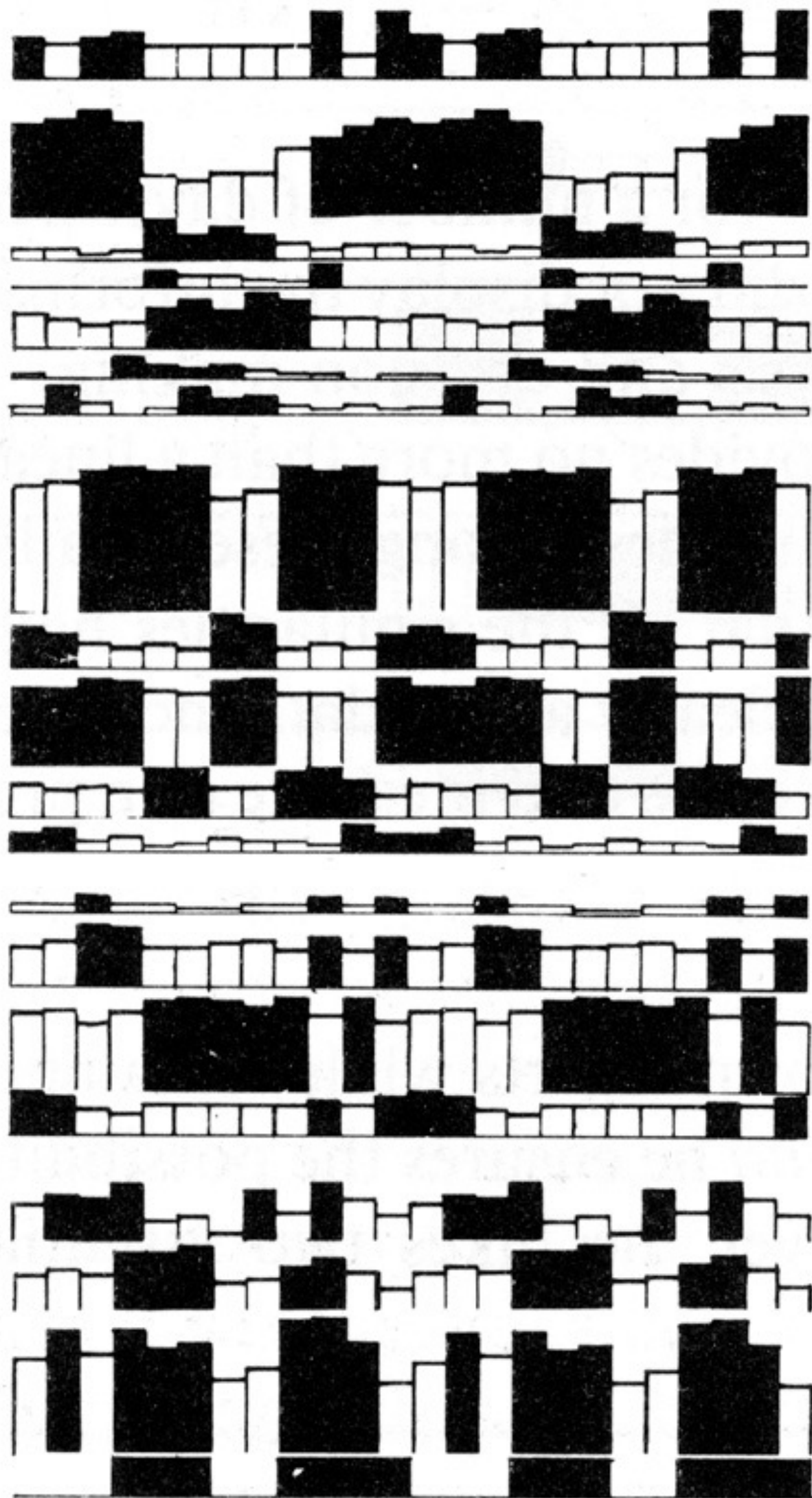






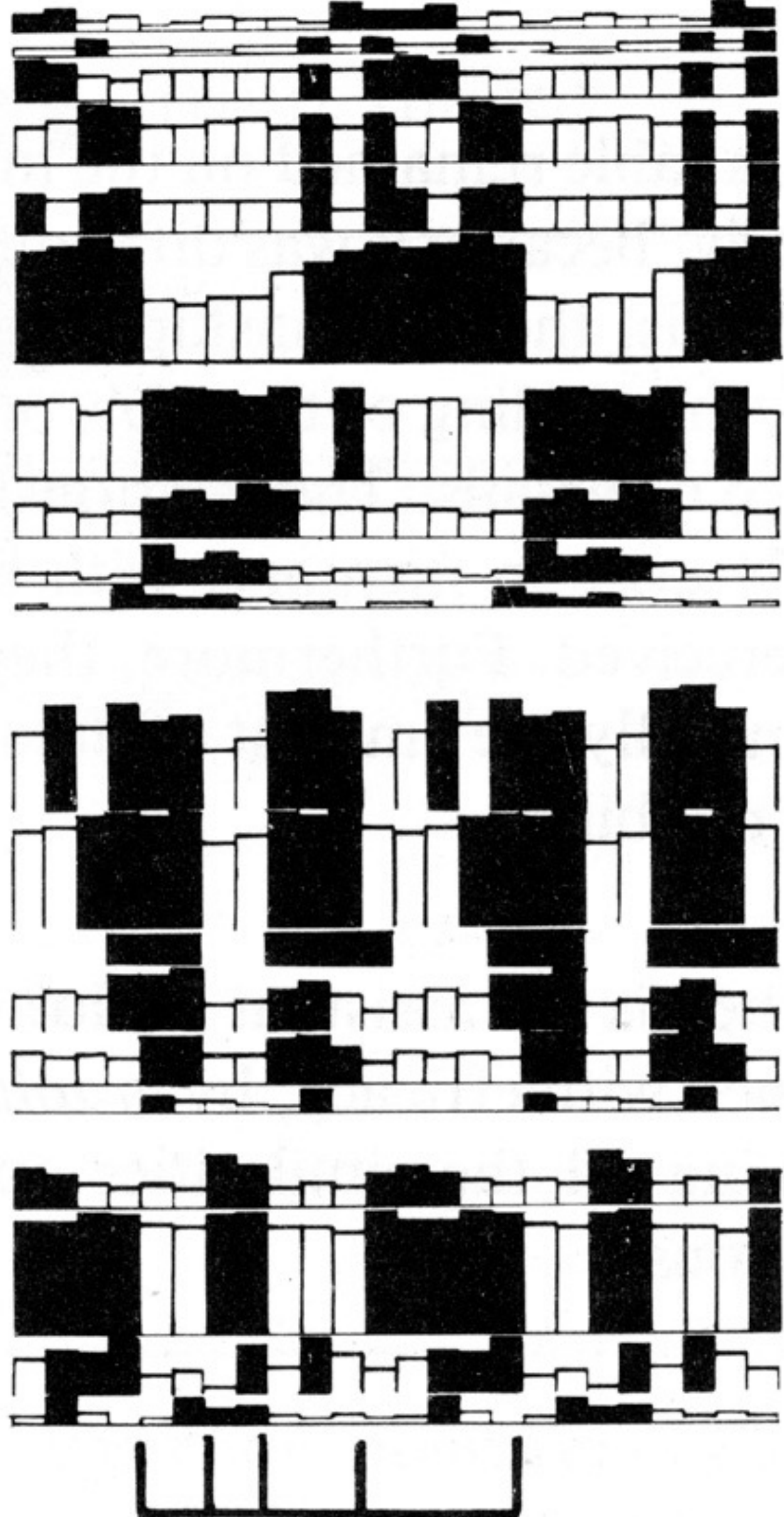
1

J FMAMJJASONDJ FMAMJJASOND



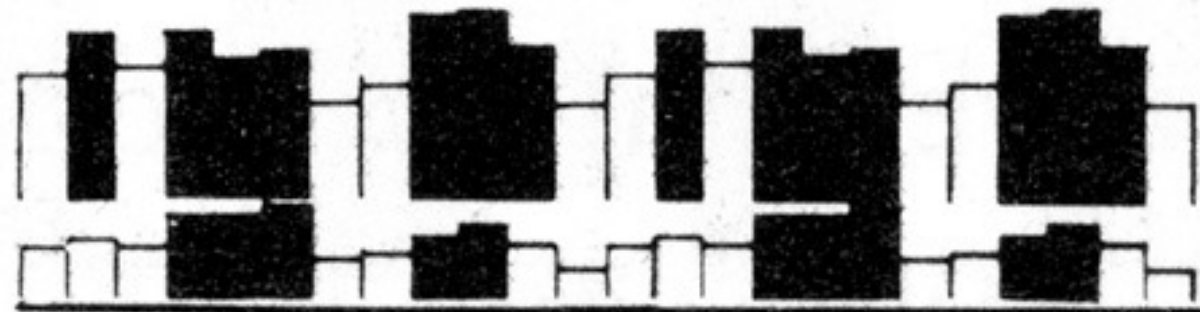
2

J FMAMJJASONDJ FMAMJJASOND





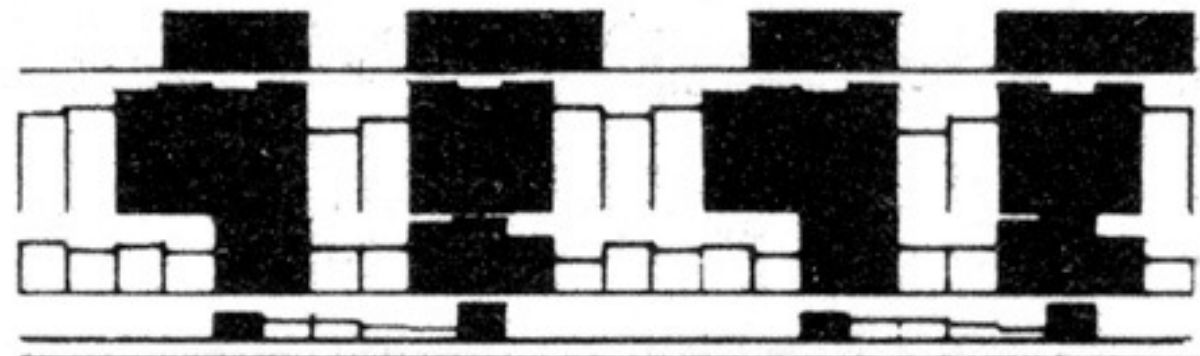
J F M A M J J A S O N D J F M A M J J A S O N D



18 % OCCUPANCY

18 LENGTH OF STAY

*ACTIVE AND SLOW PERIODS*



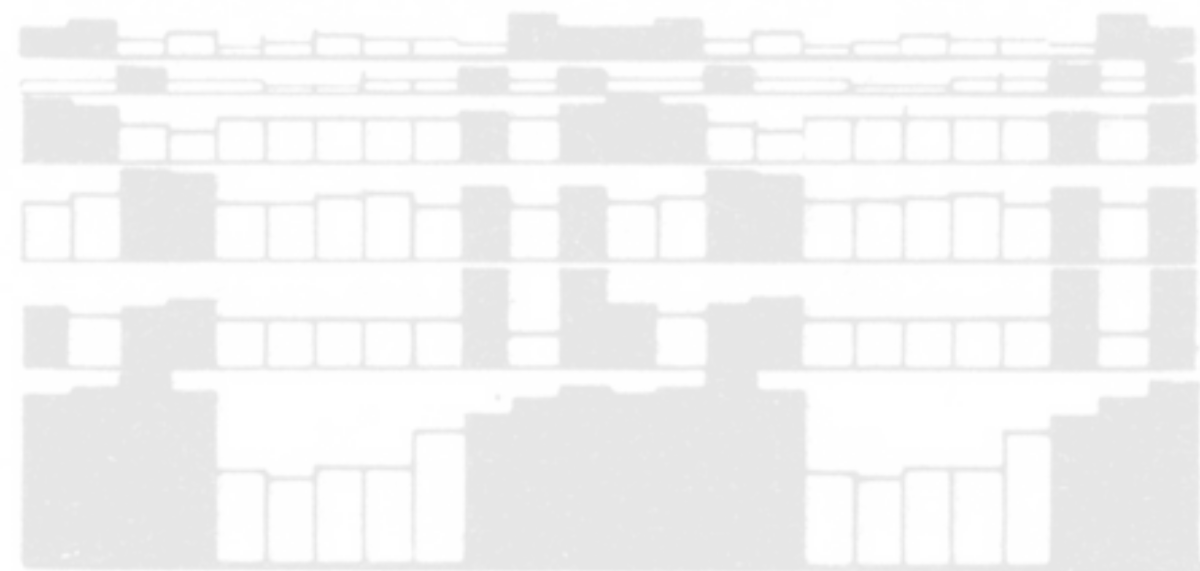
20 CONVENTIONS

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*



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



19 % OCCUPANCY

18 LENGTH OF STAY

ACTIVE AND SLOW PERIODS



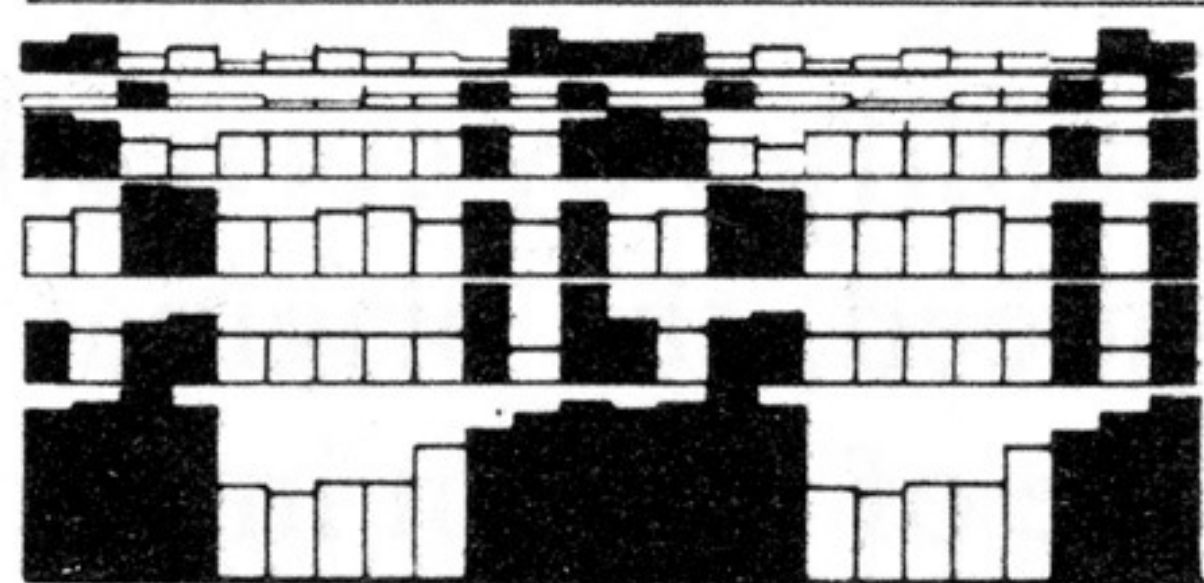
20 CONVENTIONS

8 BUSINESSMEN

11 AGENCY RESERVATIONS

4 SOUTH AMERICA

DISCOVERY FACTORS



18 AIR CREWS

18 CLIENTS UNDER 20 YEARS

18 CLIENTS MORE THAN 55 YEARS

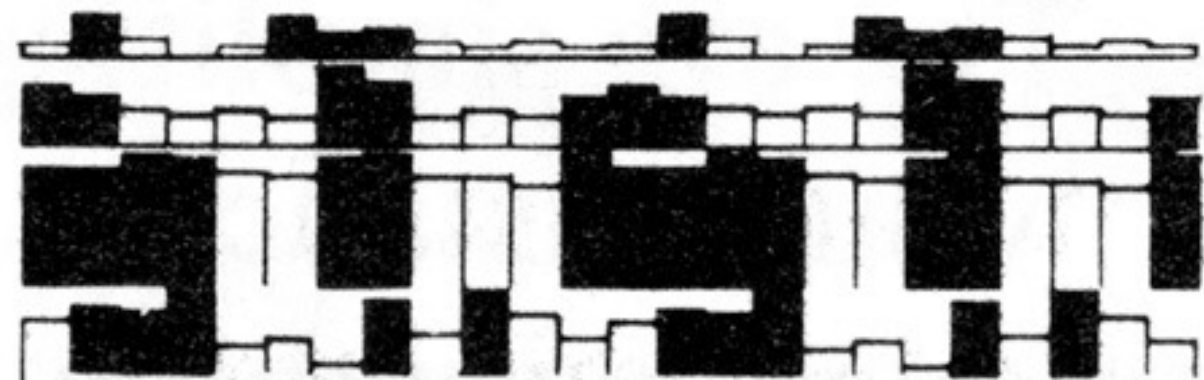
14 CLIENTS FROM 20-35 YEARS

1 FEMALE CLIENTELE

2 LOCAL CLIENTELE

RECOVERY FACTORS

WINTER



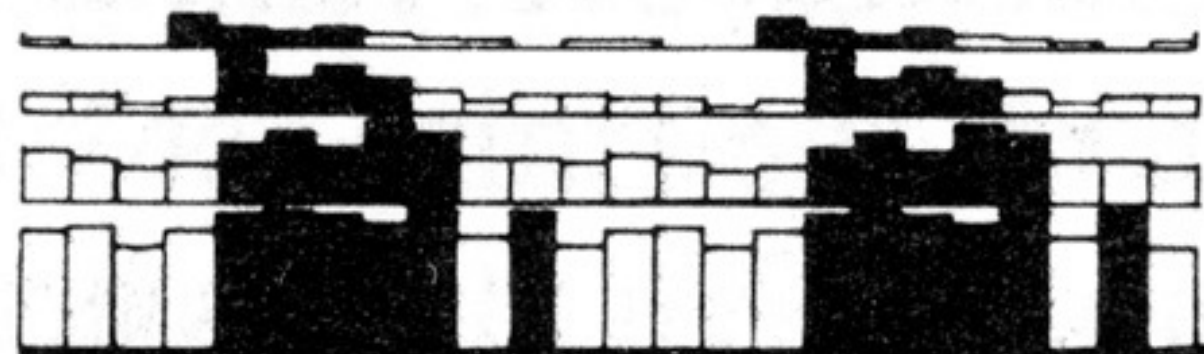
7 ASIA

9 TOURISTS

10 DIRECT RESERVATION

17 PRICE OF ROOMS

WINTER-SUMMER



6 MIDDLE EAST, AFRICA

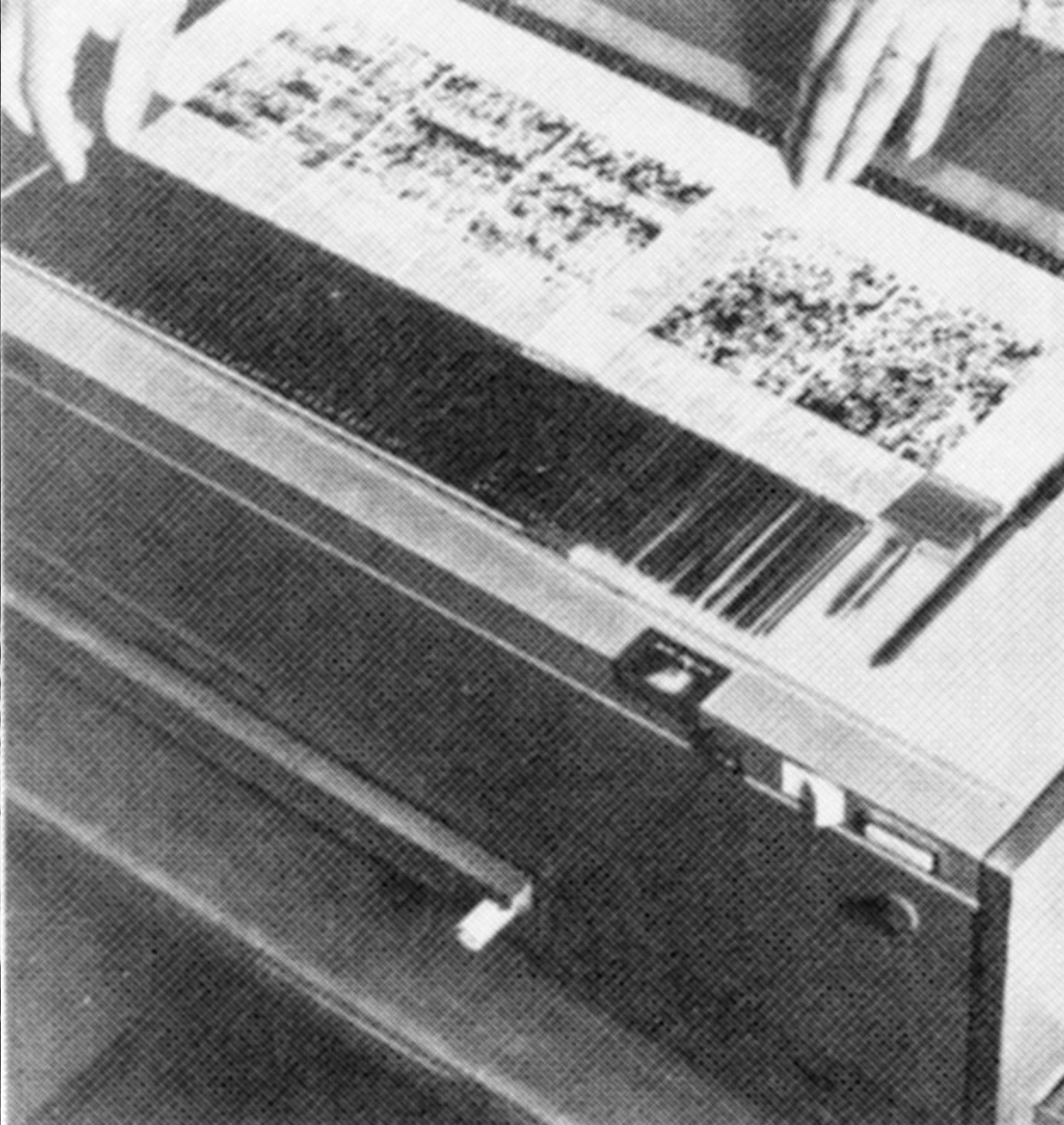
3 U. S. A.

5 EUROPE

15 CLIENTS FROM 35-55 YEARS

SUMMER





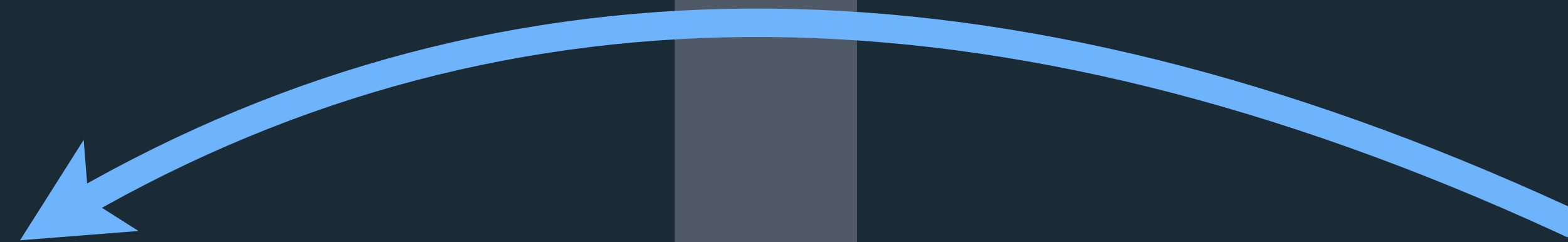


## Gulf of Evaluation

The level of difficulty in interpreting the system and assessing if goals were met.



User Goals



Interface

## Gulf of Execution

The gap between the user's goals and their ability to achieve them using the system.



day	stock	price
10/3	AMZN	957.10
10/3	MSFT	74.26
10/4	AMZN	965.45
10/4	MSFT	74.69



day	stock	price
10/3	AMZN	957.10
10/3	MSFT	74.26
10/4	AMZN	965.45
10/4	MSFT	74.69

```
select * from stocks
```



day	symbol	price
10/3	AMZN	957.10
10/4	AMZN	965.45

```
select * from stocks  
where price > 900
```



day	stock	price
10/3	AMZN	957.10
10/3	MSFT	74.26
10/4	AMZN	965.45
10/4	MSFT	74.69

```
select * from stocks
```

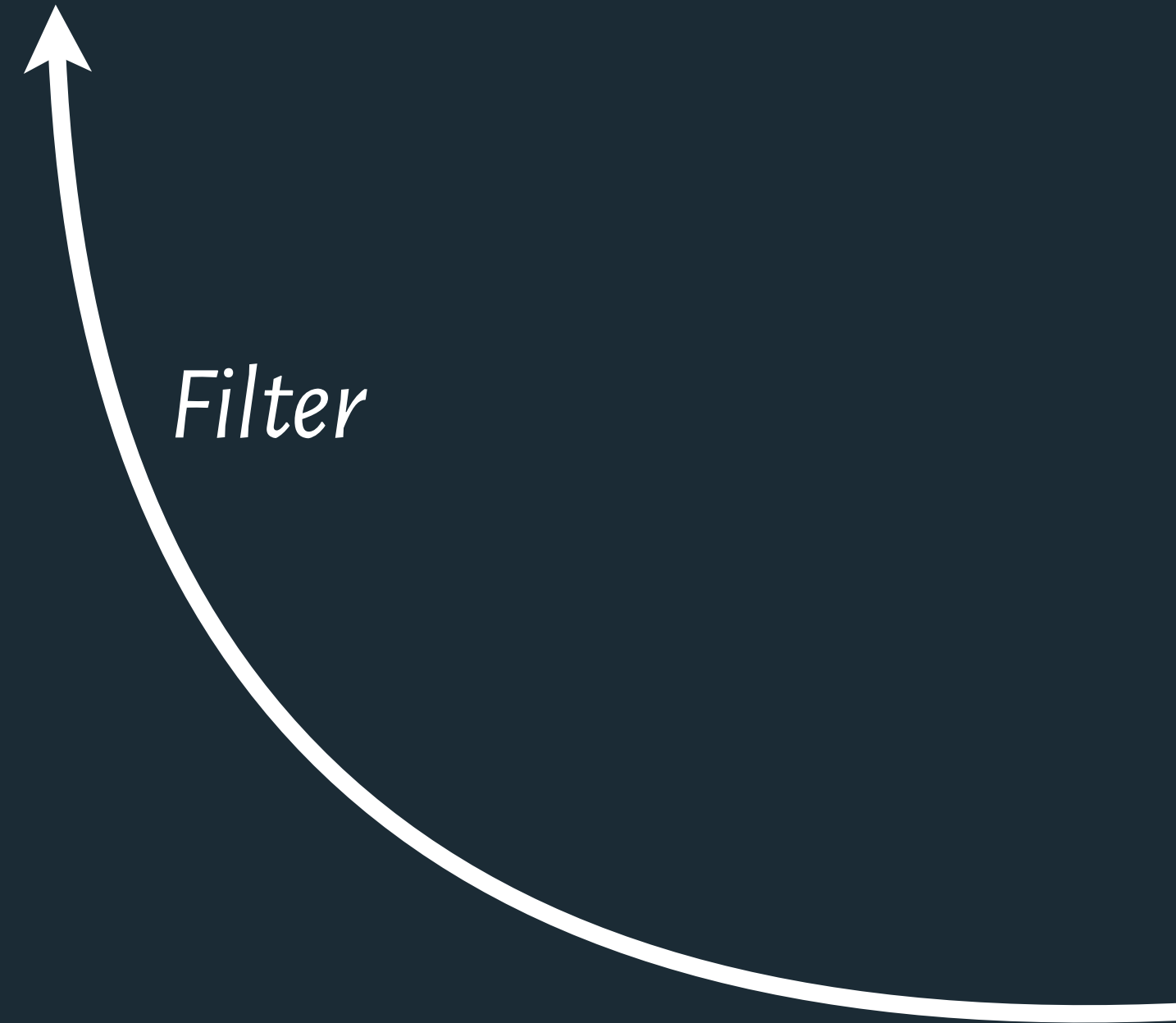


day	symbol	price
10/3	AMZN	957.10
10/4	AMZN	965.45

select \* from stocks  
where price > 900

day	symbol	price
10/3	AMZN	957.10
10/4	AMZN	965.45
10/3	MSFT	74.26
10/4	MSFT	74.69

select \* from stocks  
order by price desc



day	stock	price
10/3	AMZN	957.10
10/3	MSFT	74.26
10/4	AMZN	965.45
10/4	MSFT	74.69

select \* from stocks



day	symbol	price
10/3	AMZN	957.10
10/4	AMZN	965.45

select \* from stocks  
where price > 900

*Filter*

day	symbol	price
10/3	AMZN	957.10
10/4	AMZN	965.45
10/3	MSFT	74.26
10/4	MSFT	74.69

select \* from stocks  
order by price desc

*Sort*

symbol	avg(price)
AMZN	961.275
MSFT	74.475

select avg(price)  
from stocks  
group by symbol

*"Small Multiples" +  
Aggregation*

day	stock	price
10/3	AMZN	957.10
10/3	MSFT	74.26
10/4	AMZN	965.45
10/4	MSFT	74.69

select \* from stocks



- ✗ Results returned as a table.
- ✗ No hint on how to reformulate query.
- ✗ Slow question-answer loop.

## Gulf of Evaluation



User Goals

SQL



Interface

## Gulf of Execution

- ✗ A rigid syntax designed by/for programmers.
- ✗ Difficult to do "fuzzy" matching.





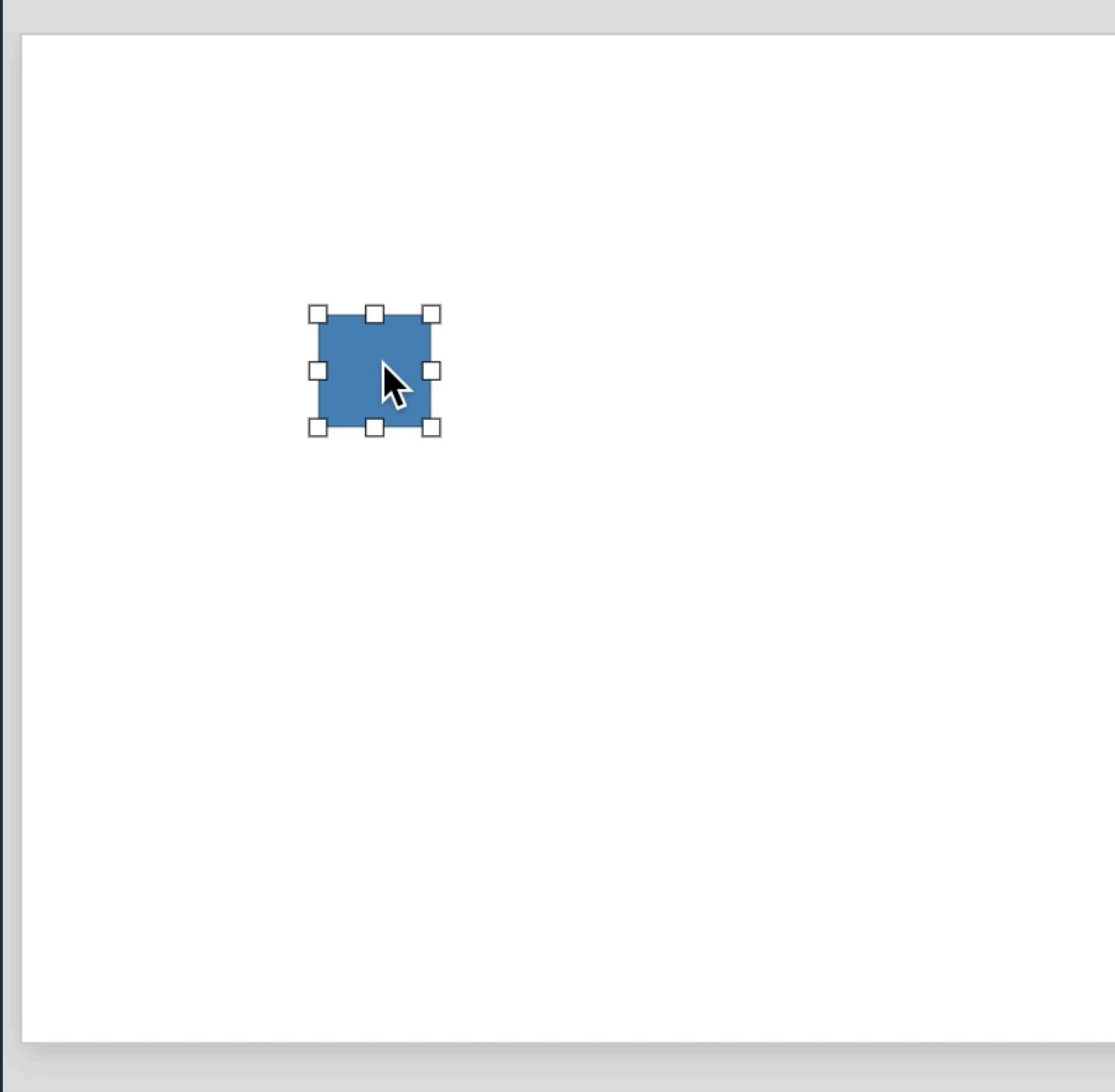
Elements Console Sources Network Performance Memory Application >> | ⋮ | ✕

top Filter All levels ▾ | ⚙

```
> var canvas = document.querySelector('canvas');
```

```
< undefined
```

```
> var ctx = canvas.getContext|
```





- ✓ Visual representation of objects + actions.
- ✓ Immediate + continuous display of results.

## Gulf of Evaluation



User Goals

# Direct Manipulation



Interface

## Gulf of Execution

- ✓ Physical actions or labeled buttons instead of complex syntax.
- ✓ Rapid, incremental, and reversible actions.



# Interaction with Visualization

**Select** – identify something as interesting.

**Connect** – show me related items.

**Abstract/Elaborate** – show me more or less detail.

**Filter** – show me something conditionally.

**Reconfigure** – show me a different arrangement.

**Explore** – show me something else.

**Encode** – show me a different visual representation.



# *Point* Selection

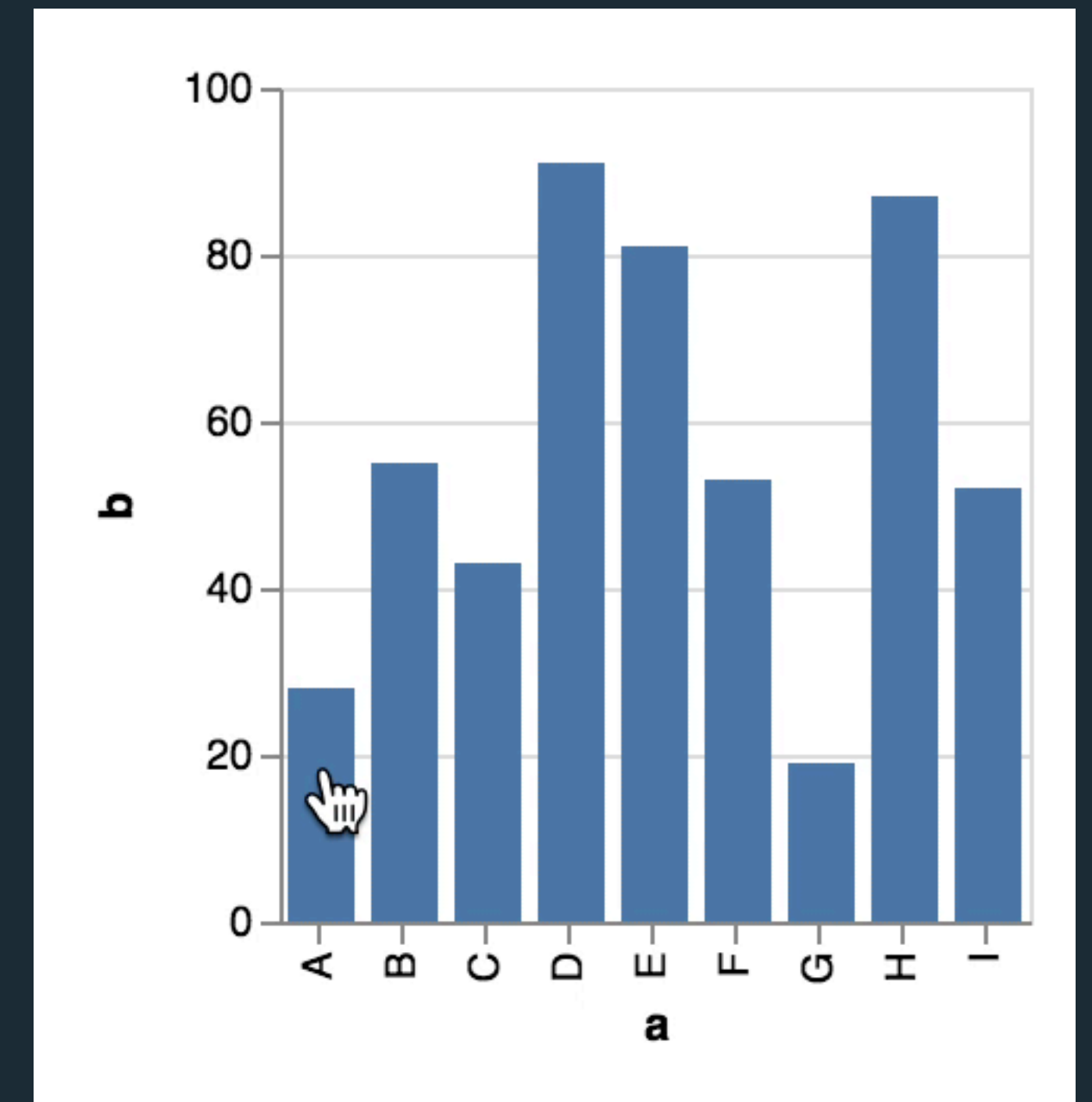
Select discrete data values.



# Point Selection

Select discrete data values.

How many points are selected? 1, 2, 3, ...

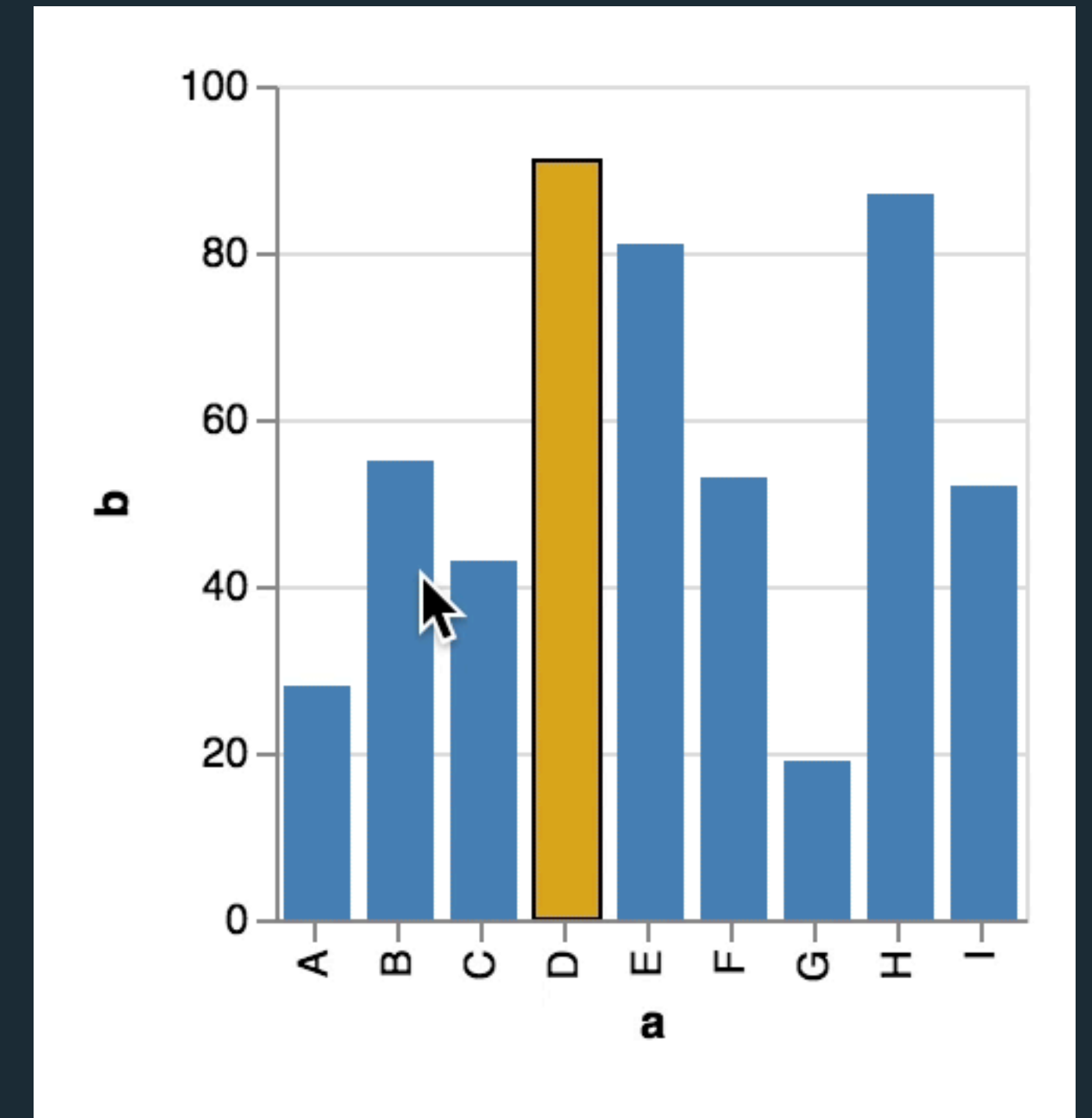


# Point Selection

Select discrete data values.

How many points are selected? 1, 2, 3, ...

How are points selected? Mouse hover, click, tap, ...

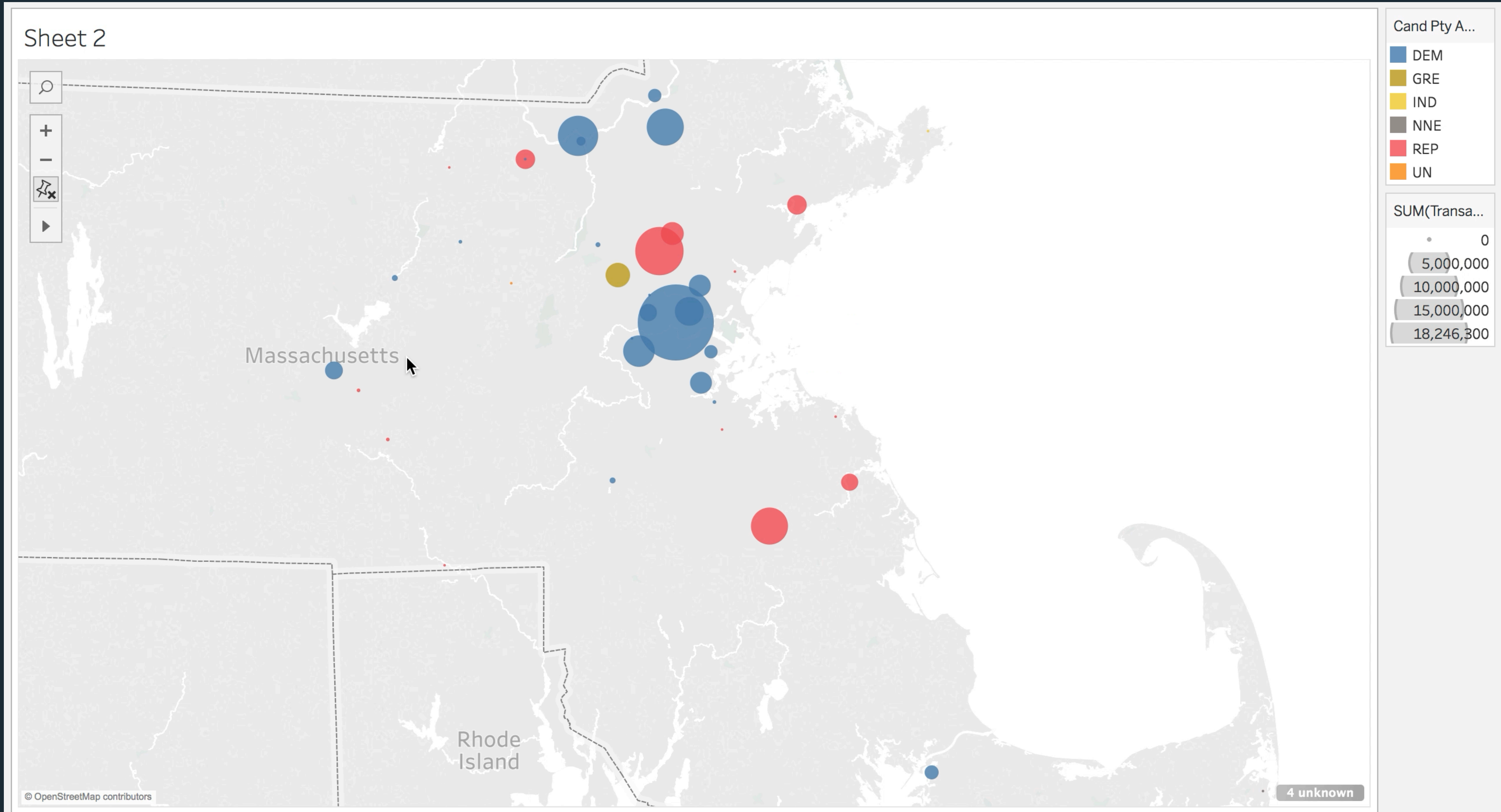




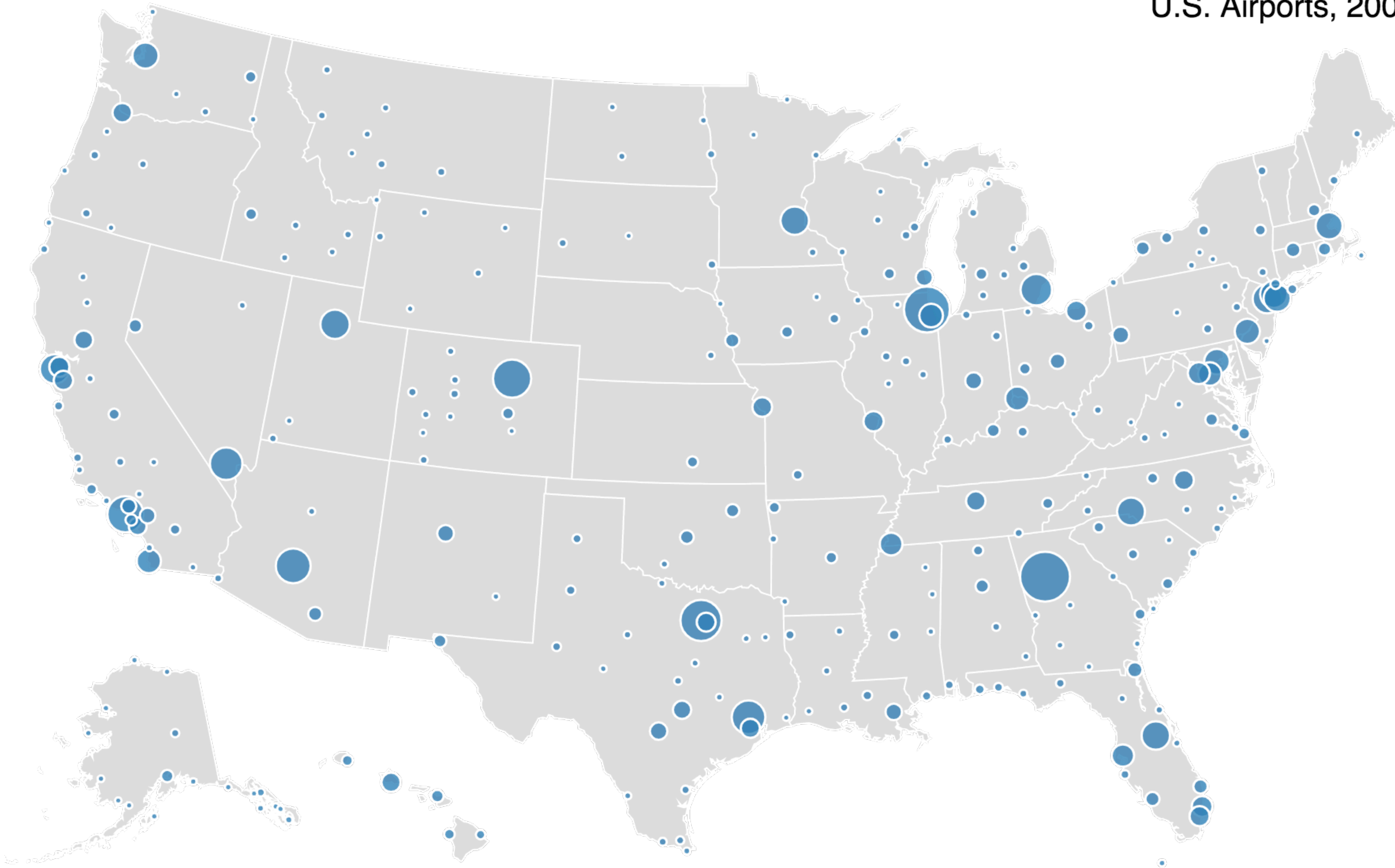
# Region Selection

**Extensional** Selections: enumerate all points

**Intentional** Selections: describes common properties

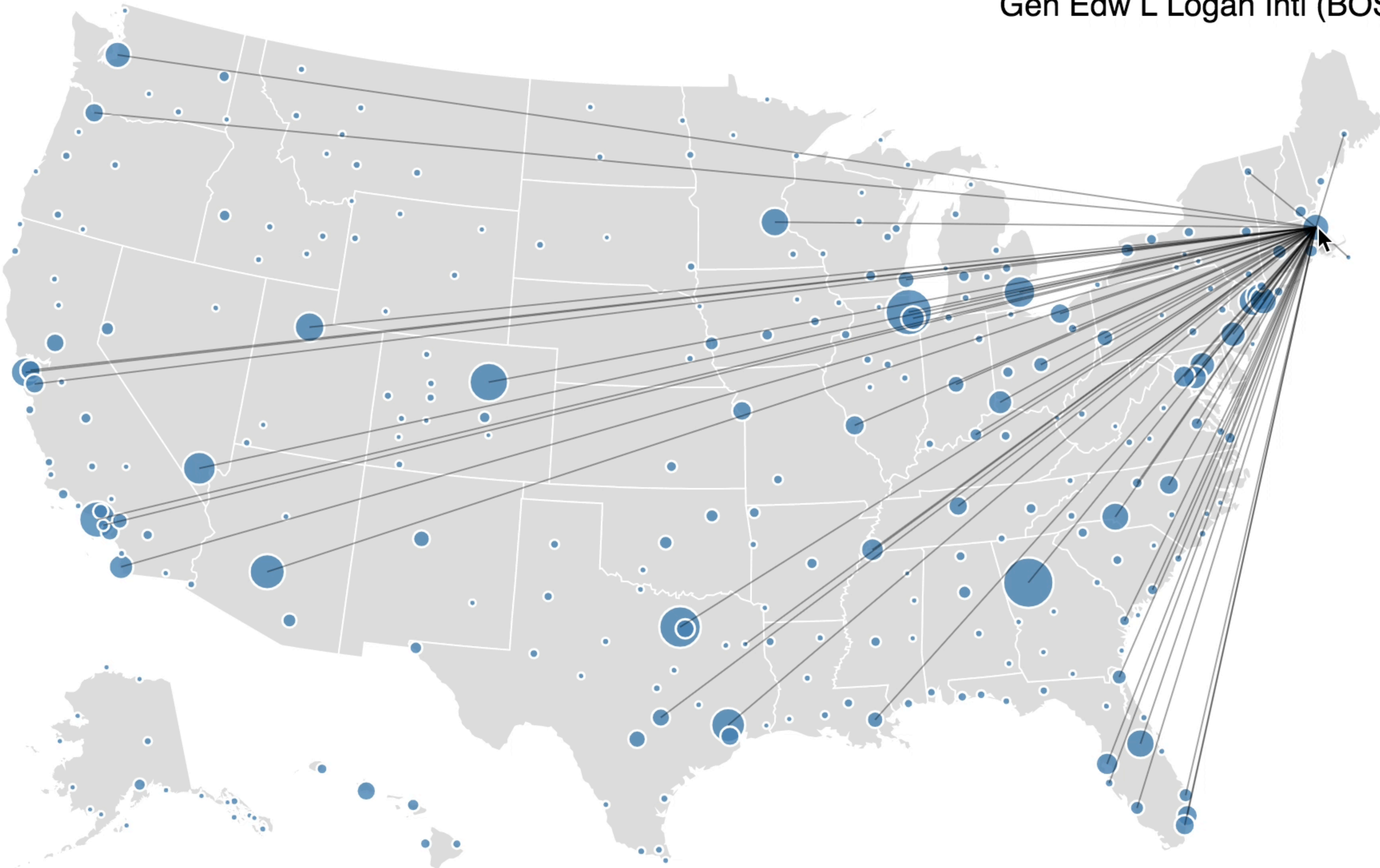


U.S. Airports, 2008

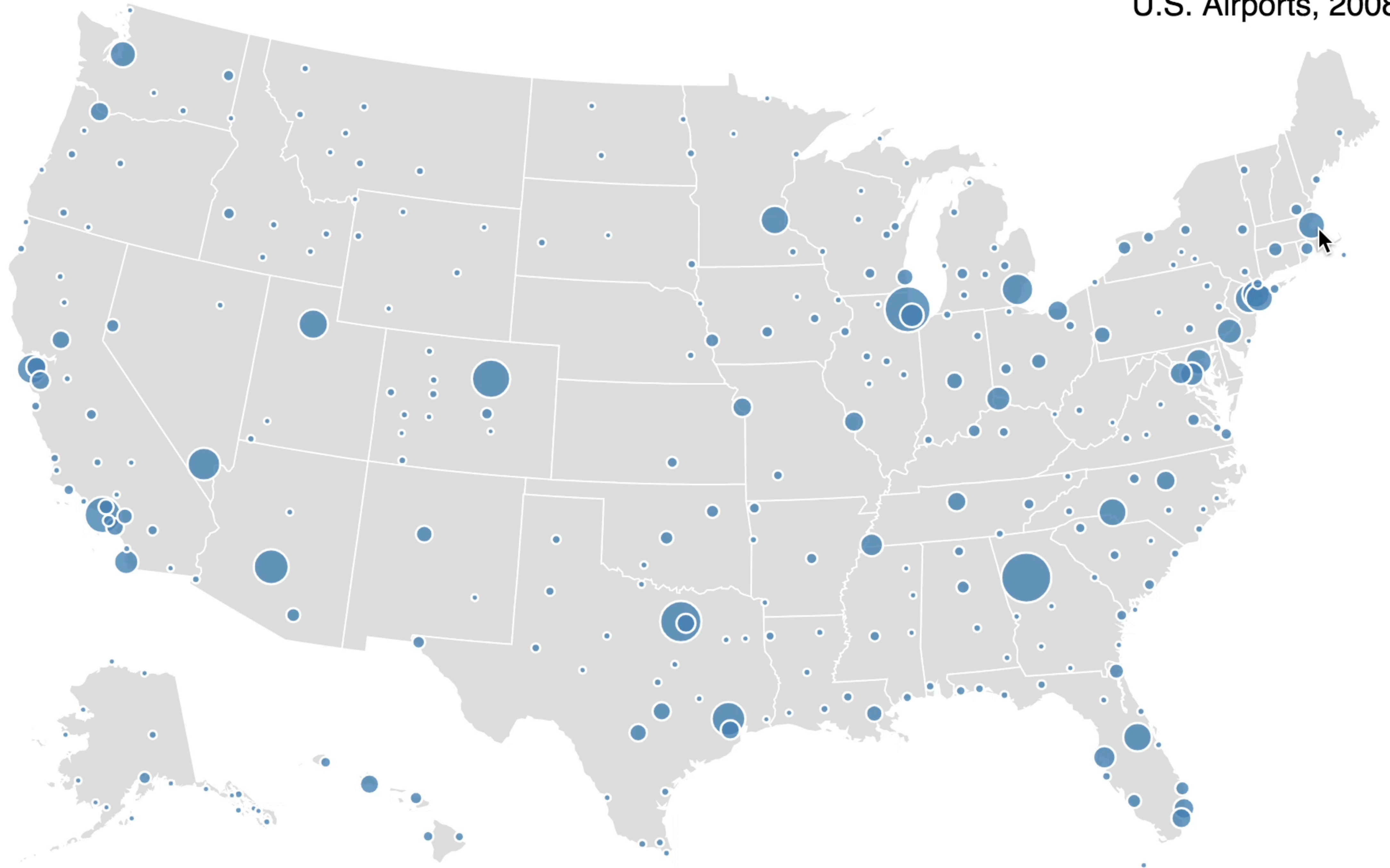




Gen Edw L Logan Intl (BOS)

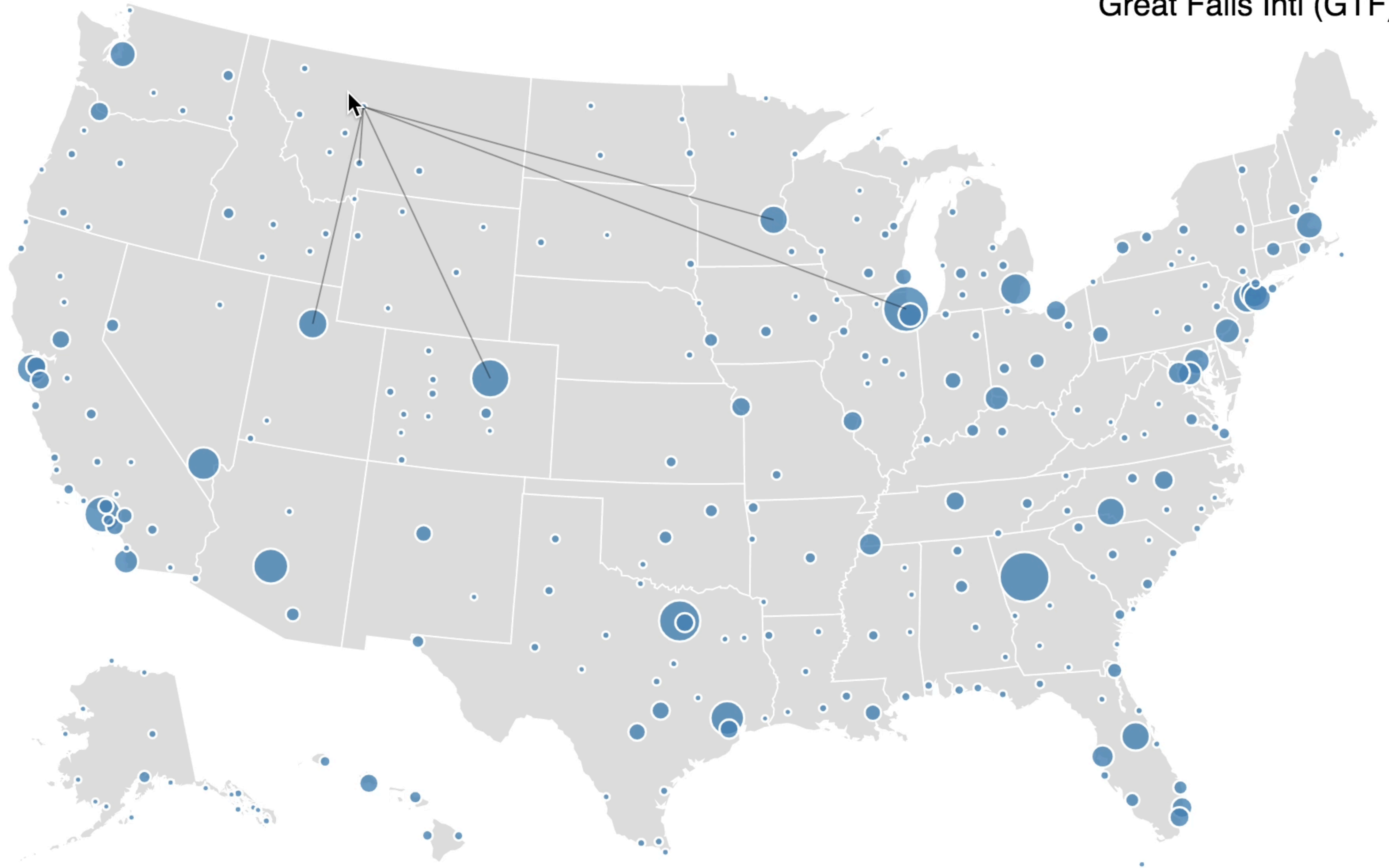


# U.S. Airports, 2008





# Great Falls Intl (GTF)



# Generalized Selection via Interactive Query Relaxation

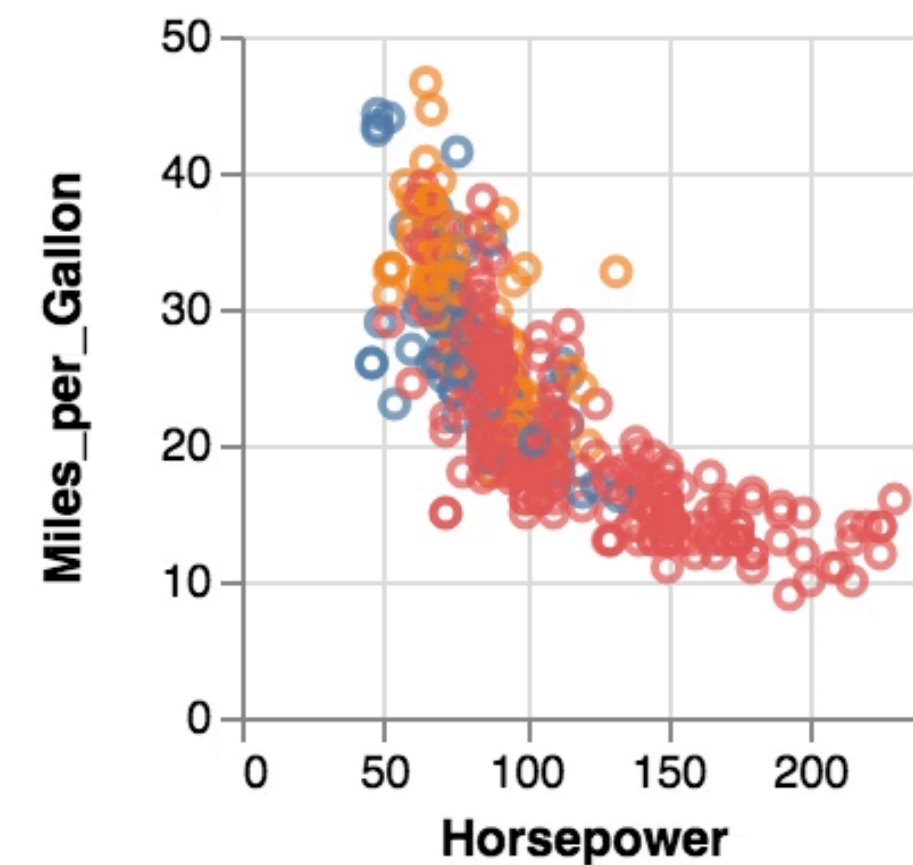
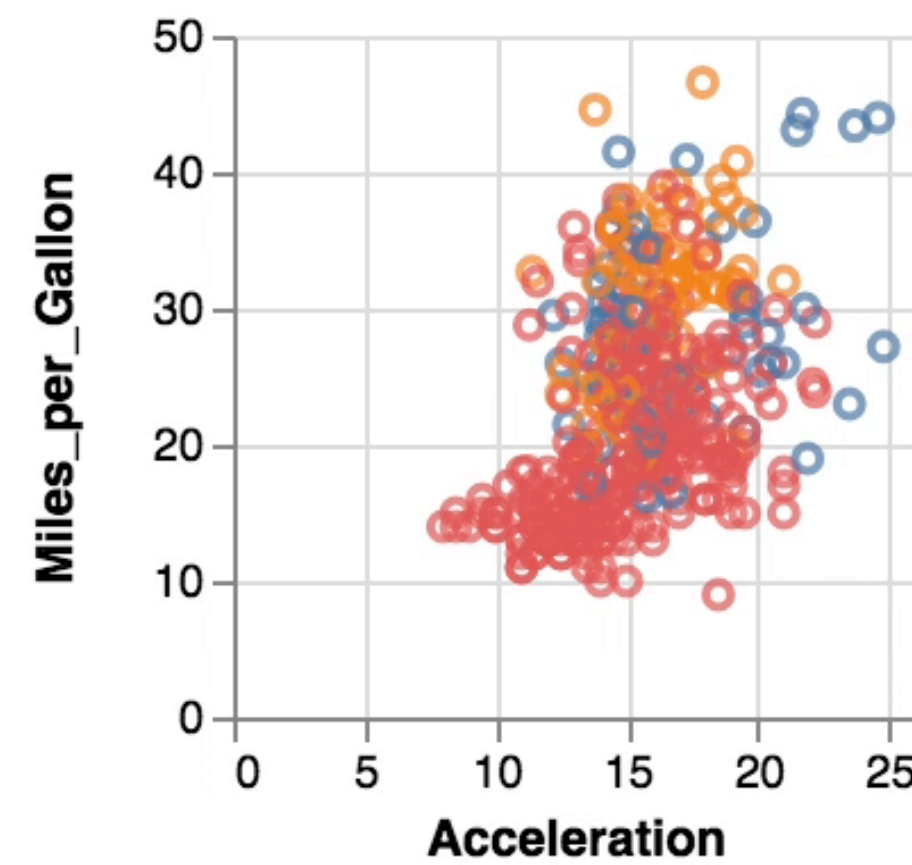
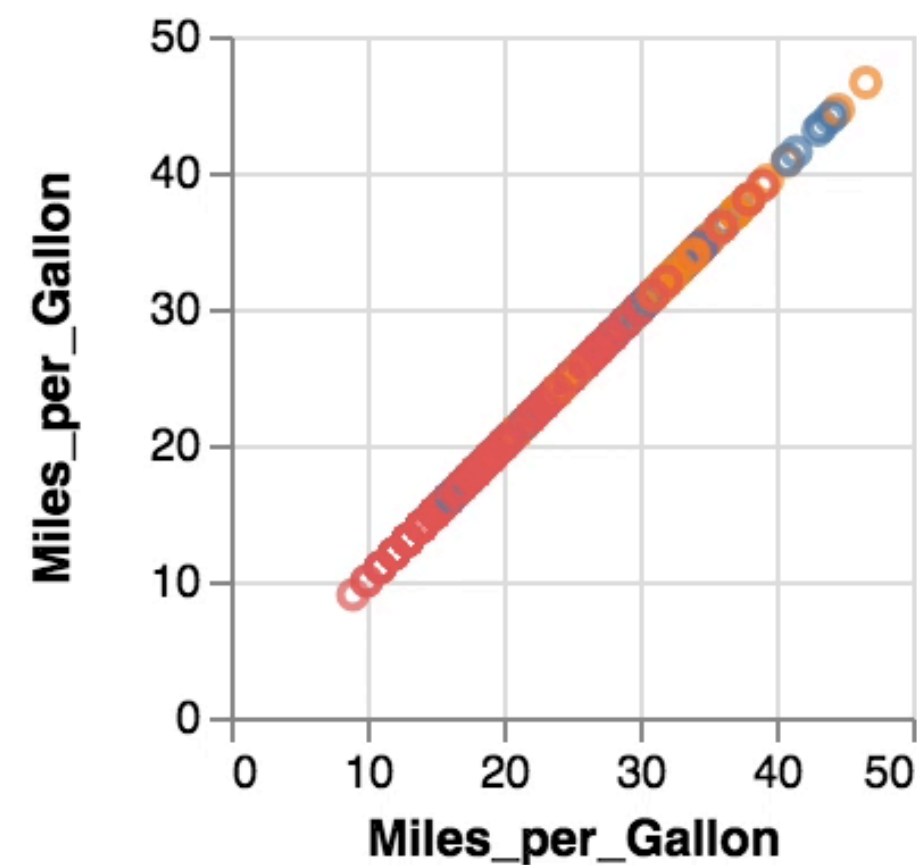
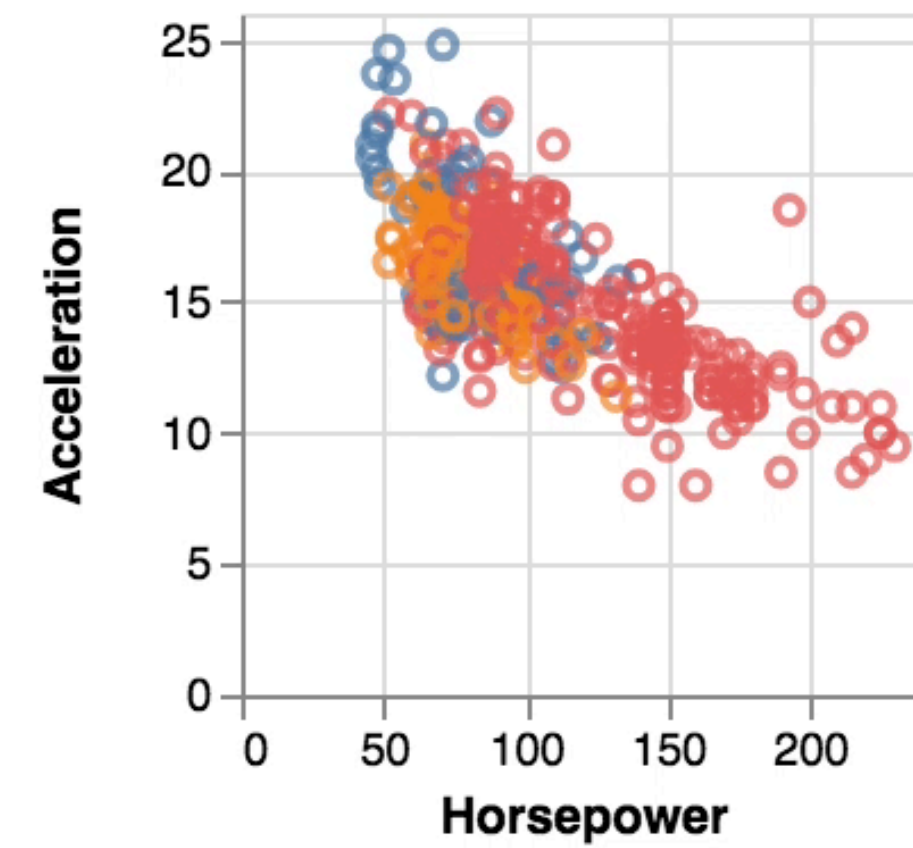
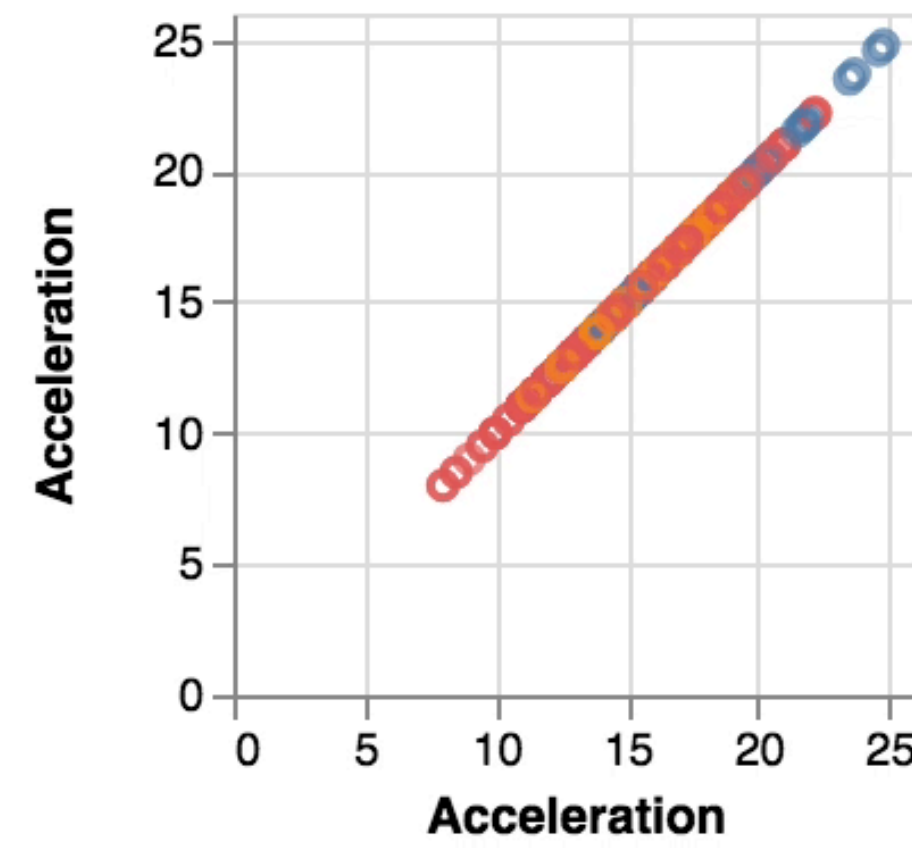
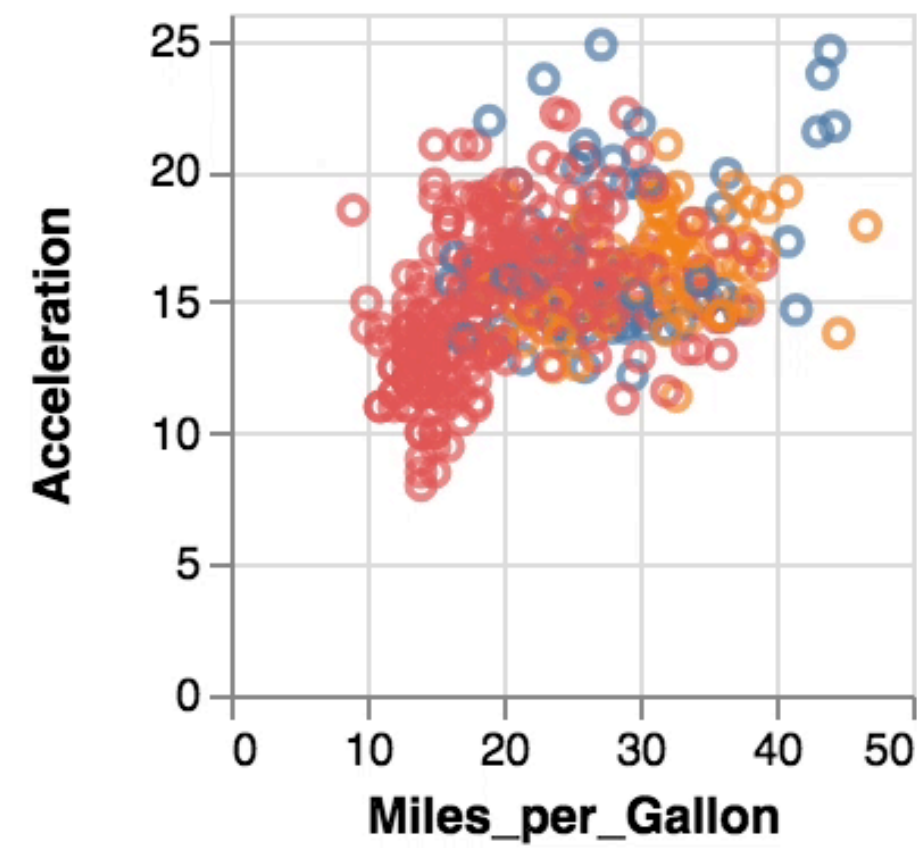
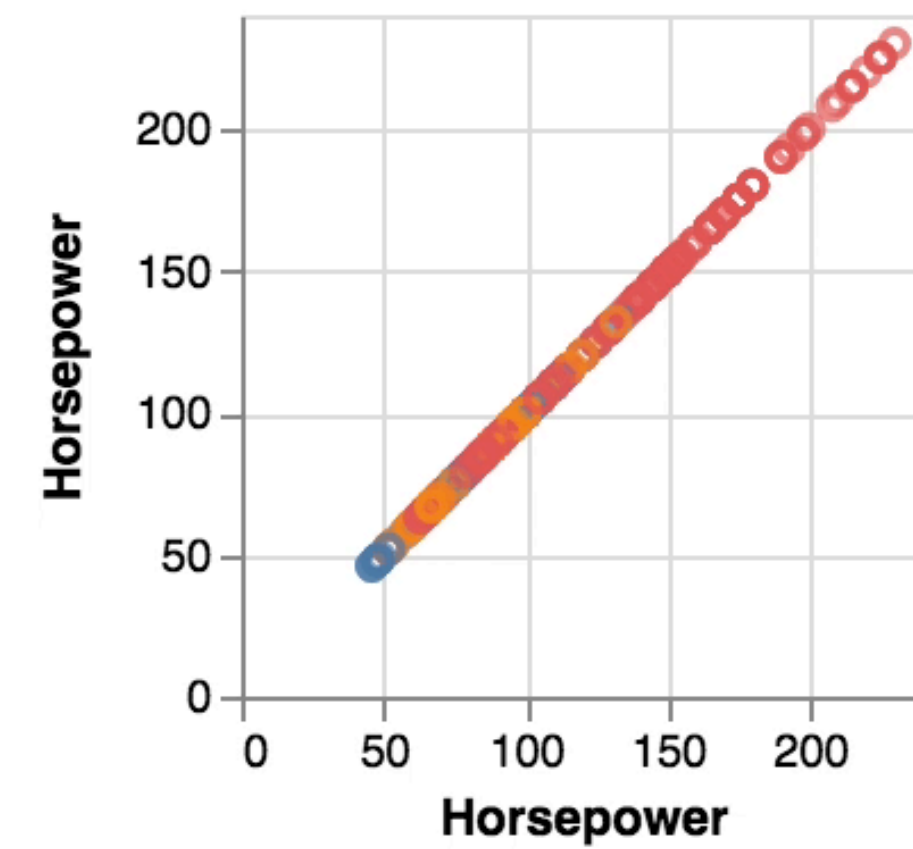
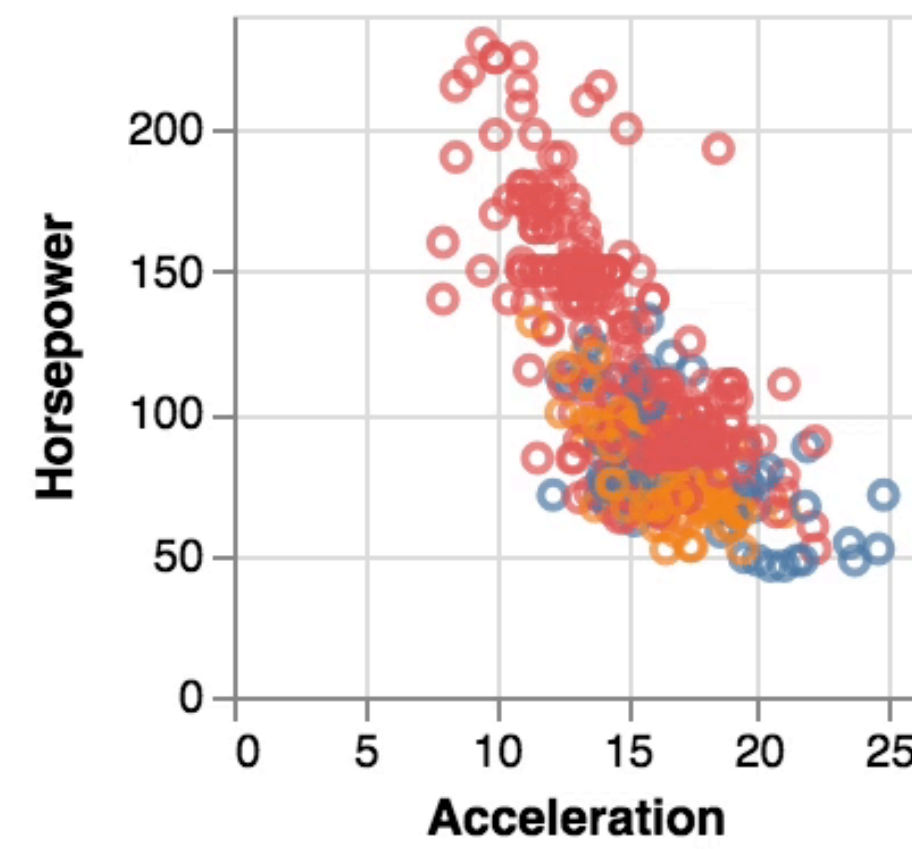
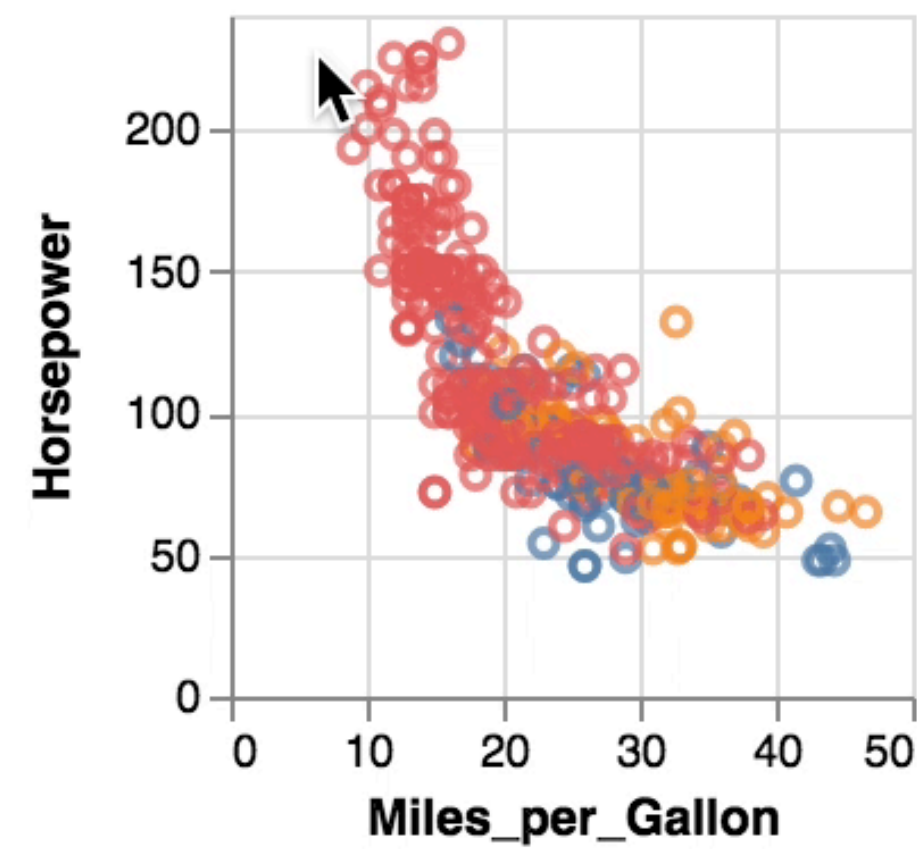
Jeffrey Heer | Maneesh Agrawala | Wesley Willett  
University of California, Berkeley



# Connect

Brushing & linking: selection is called a "brush", and the selected data is shown ("linked") in other views.

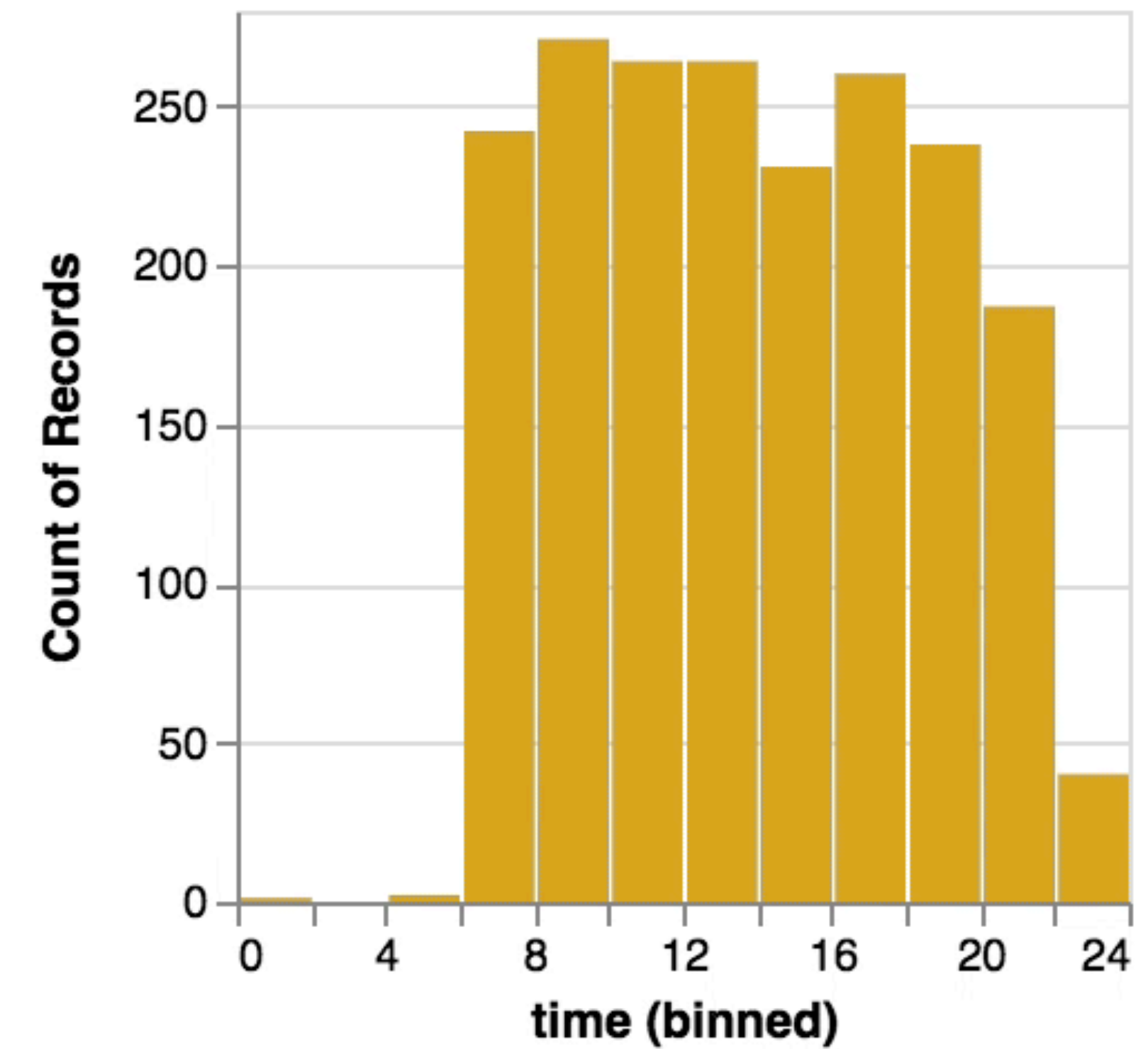
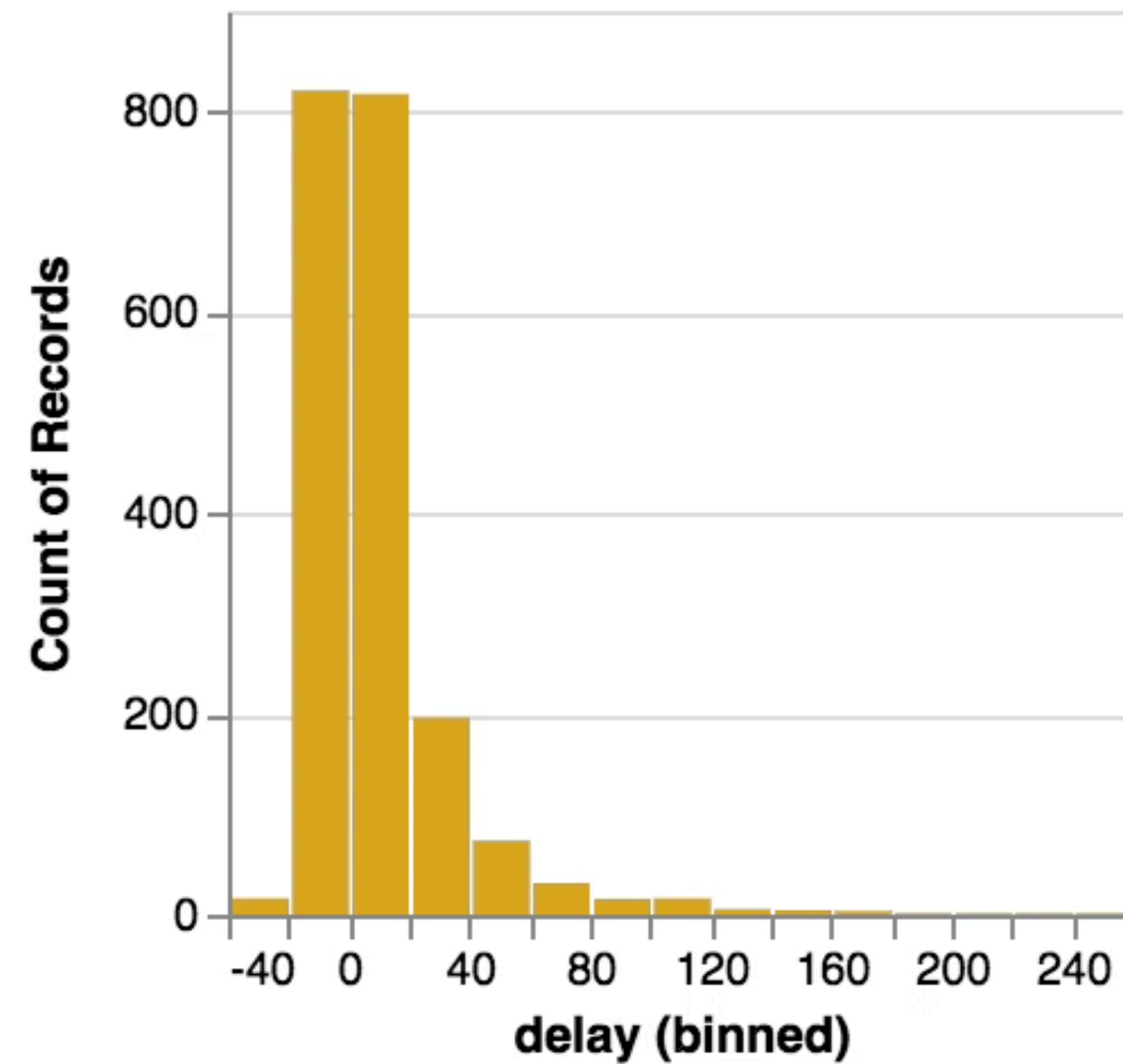
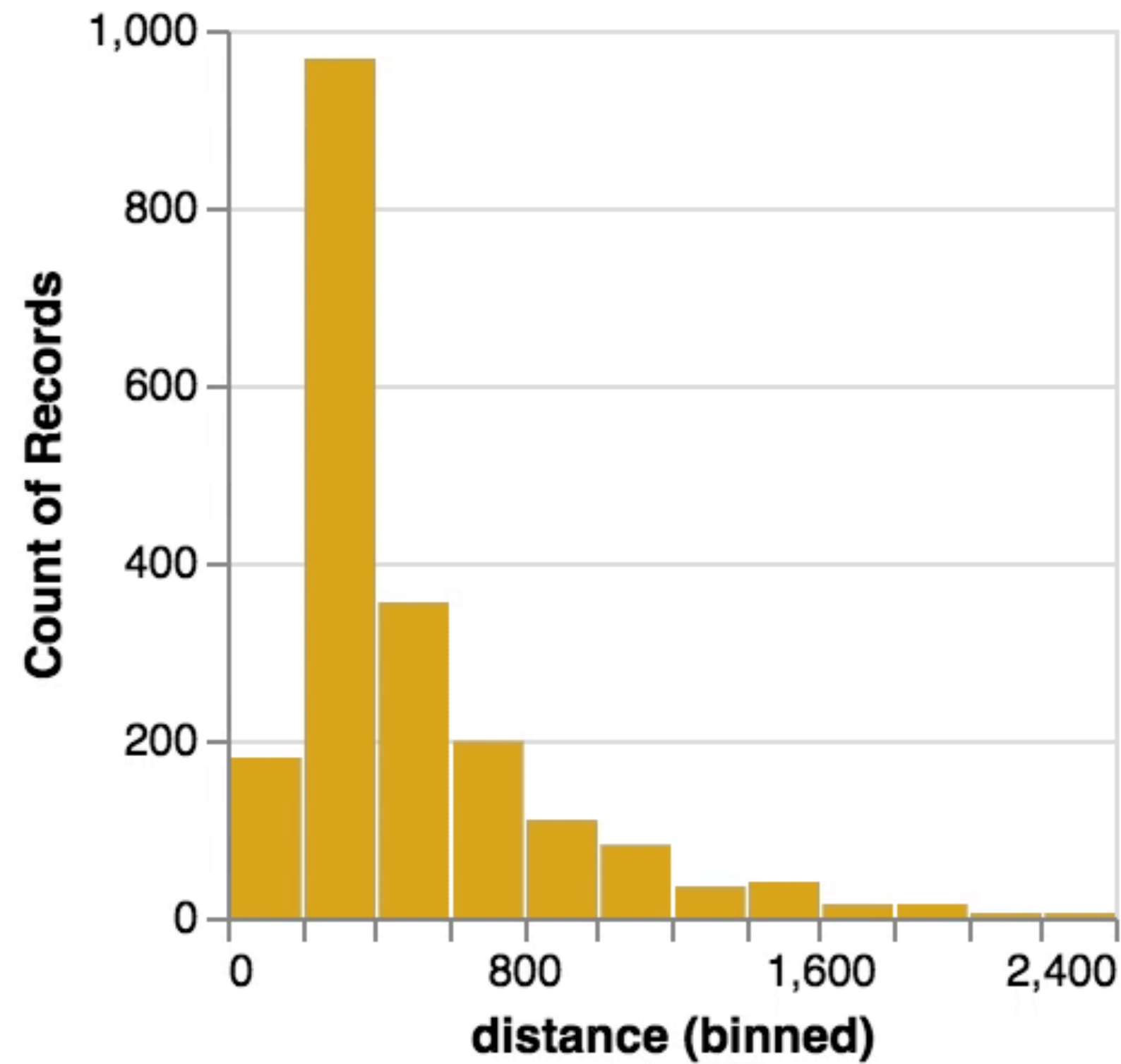
Link by *tuple* (i.e., explicitly identify and match the same data values across every view).



# Connect

Link by *query* (i.e., matching range or values of fields).

Type of linking operation is not dependent on selection type (i.e., point and region selections can both be used to link by either tuple or query).





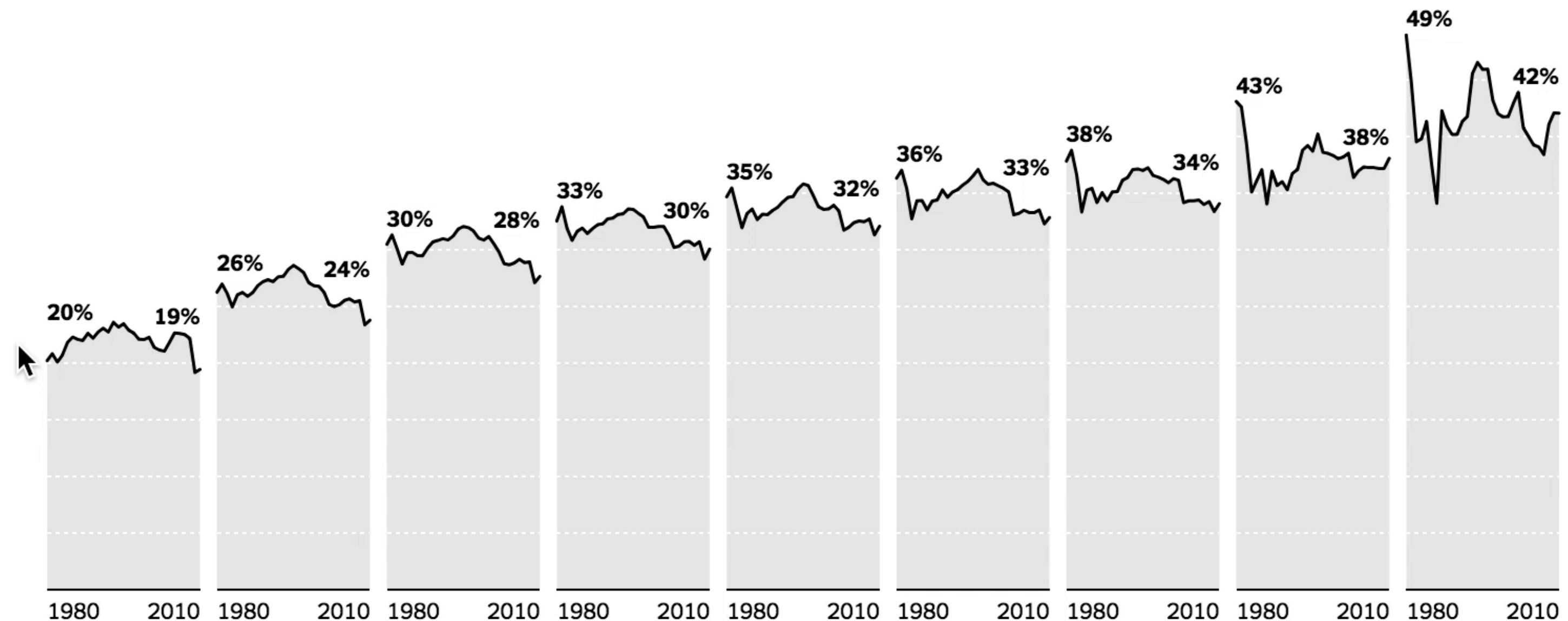
# How the Tax Burden Has Changed

Most Americans paid less in taxes in 2010 than people with the same inflation-adjusted incomes paid in 1980, because of cuts in federal income taxes. At lower income levels, however, much of the savings was offset by increases in federal payroll taxes, state sales taxes and local property taxes. About half of households making less than \$25,000 saved nothing at all. [About the Data »](#) | [Related Article »](#)

- \$0-25k
- \$25-50k
- \$50-75k
- \$75-100k
- \$100-125k
- \$125-150k
- \$150-200k
- \$200-350k
- \$350k+

## Tax rates have fallen for most Americans, especially high earners.

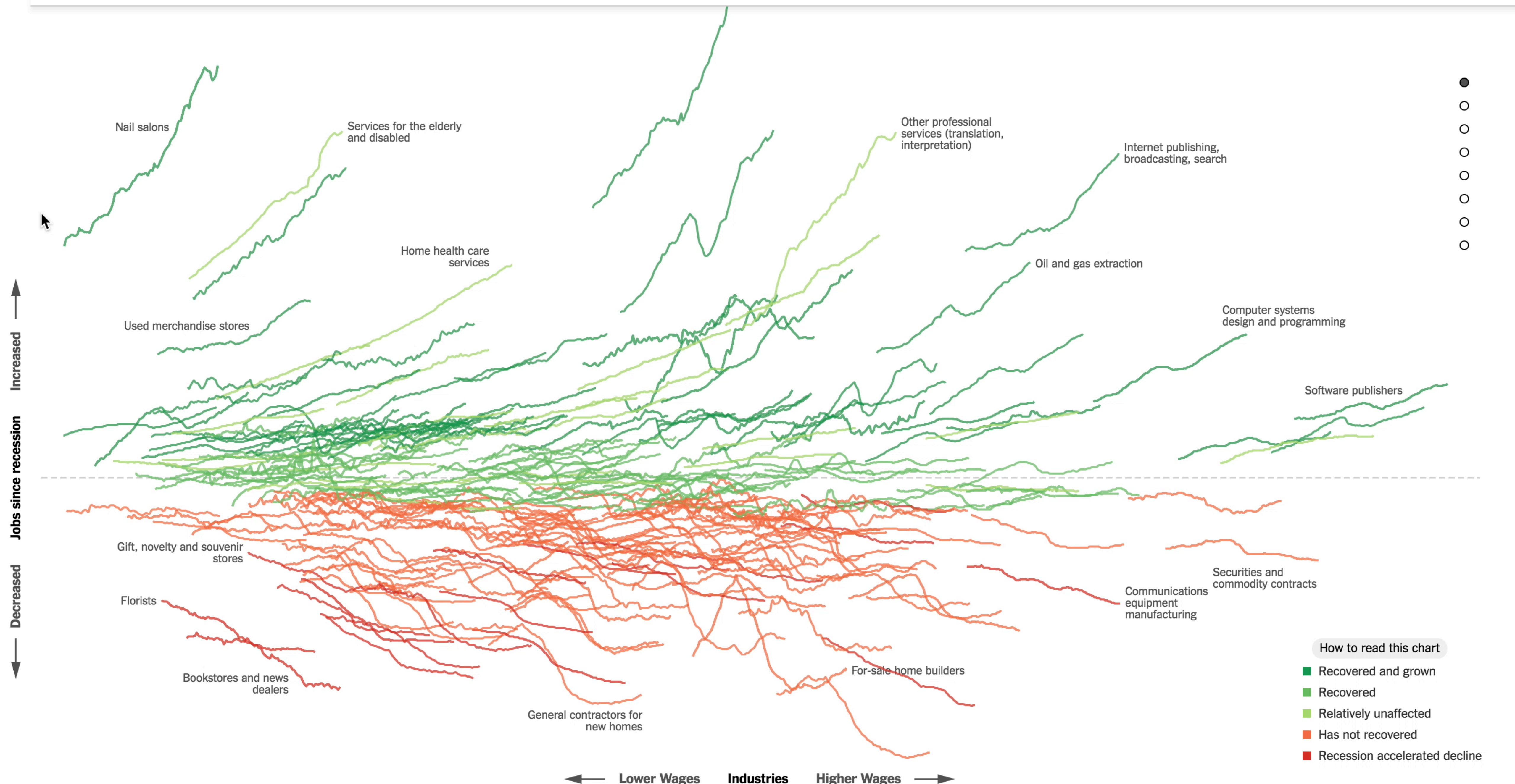
Share of yearly income paid in federal, state and local taxes, by income bracket.



Connect

# Abstract/Elaborate

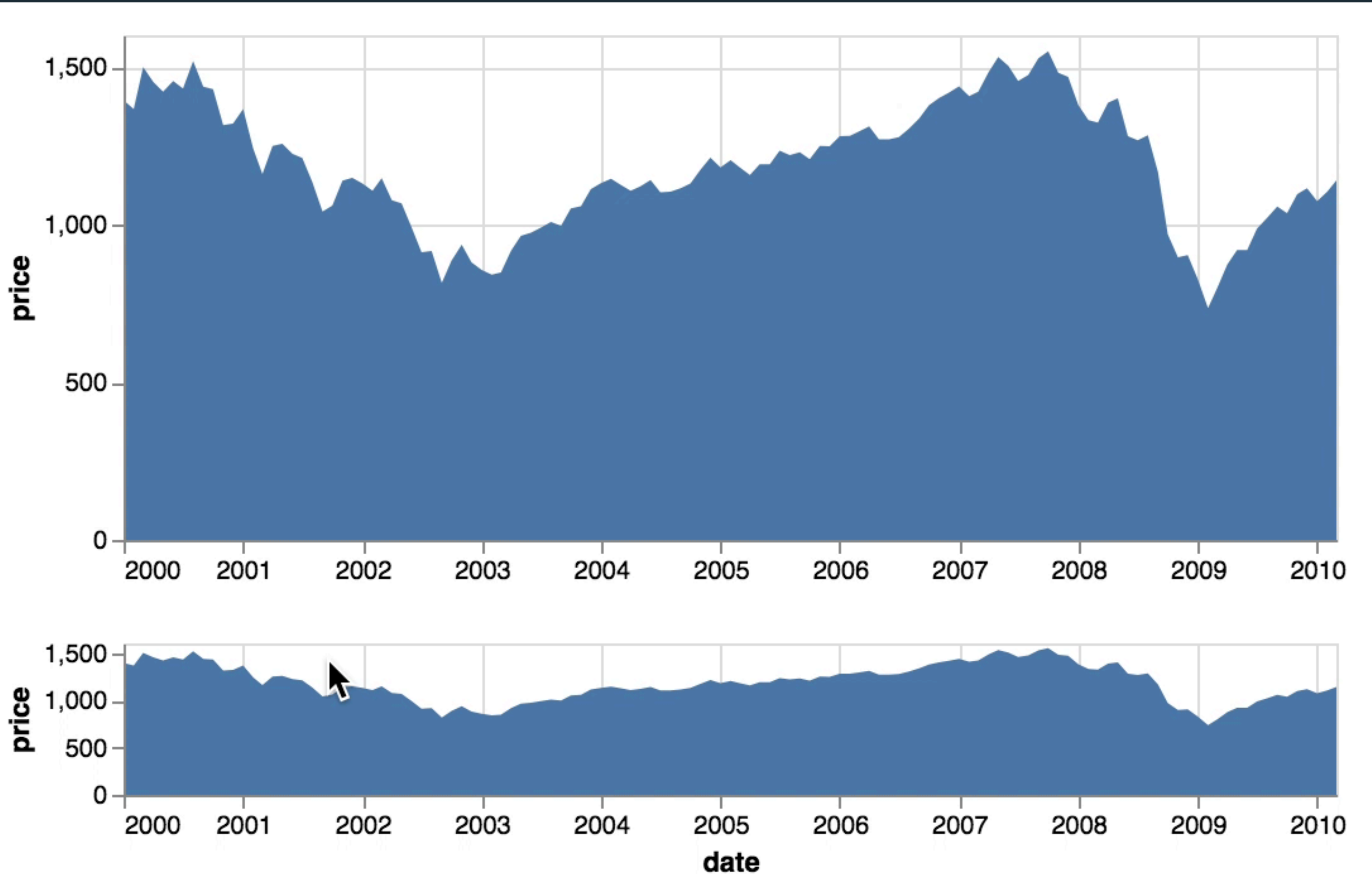






# Abstract/Elaborate

## Overview + Detail





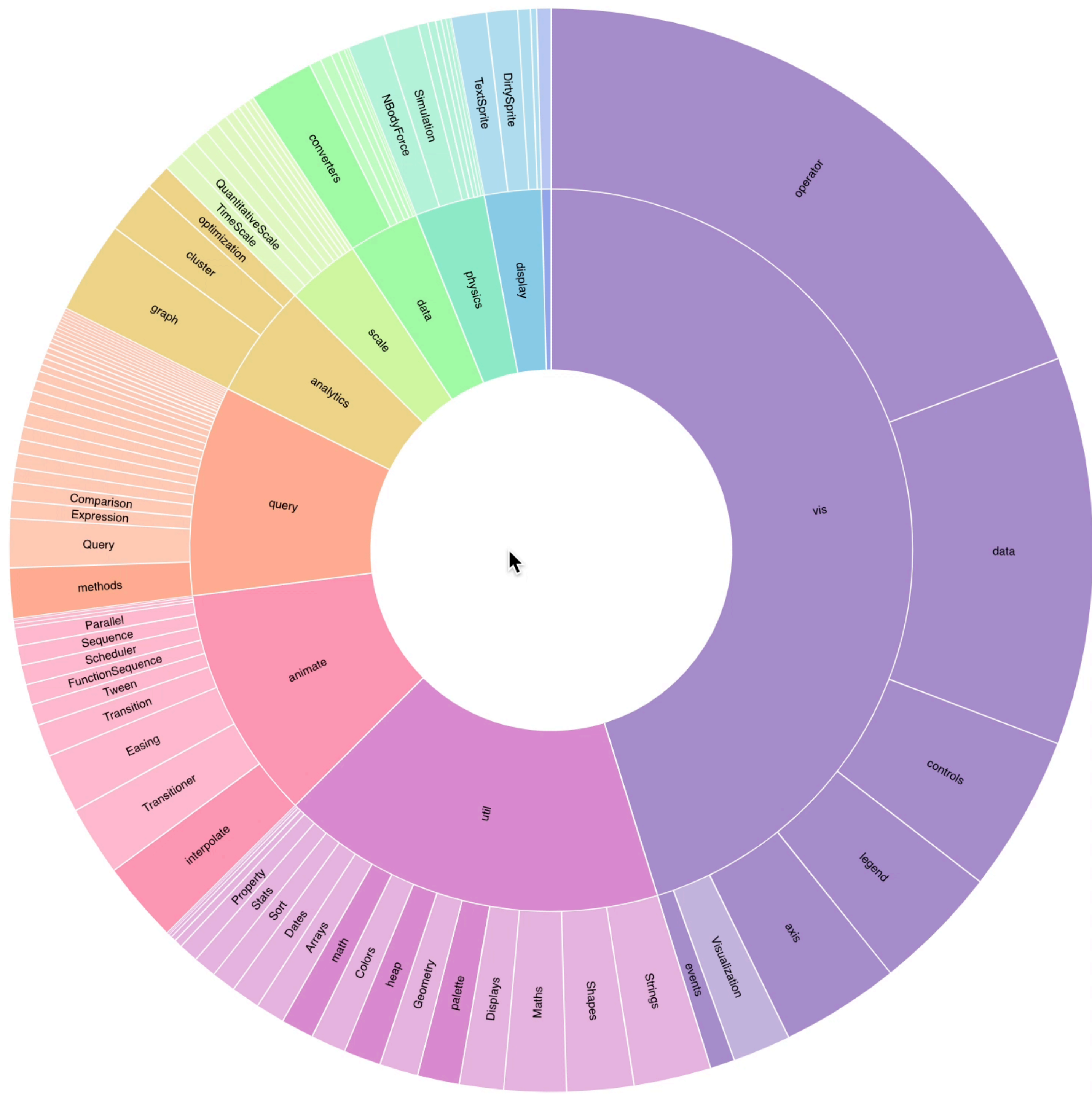
# SchemeLens

## A Content-Aware Vector-Based Fisheye Technique for Navigating Large Systems Diagrams

**Aurélie Cohe, Bastien Liutkus, Gilles Bailly, James Eagan, Eric Lecolinet**

**Télécom ParisTech - CNRS LTCI - VIA Group**

**InfoVis 2015**

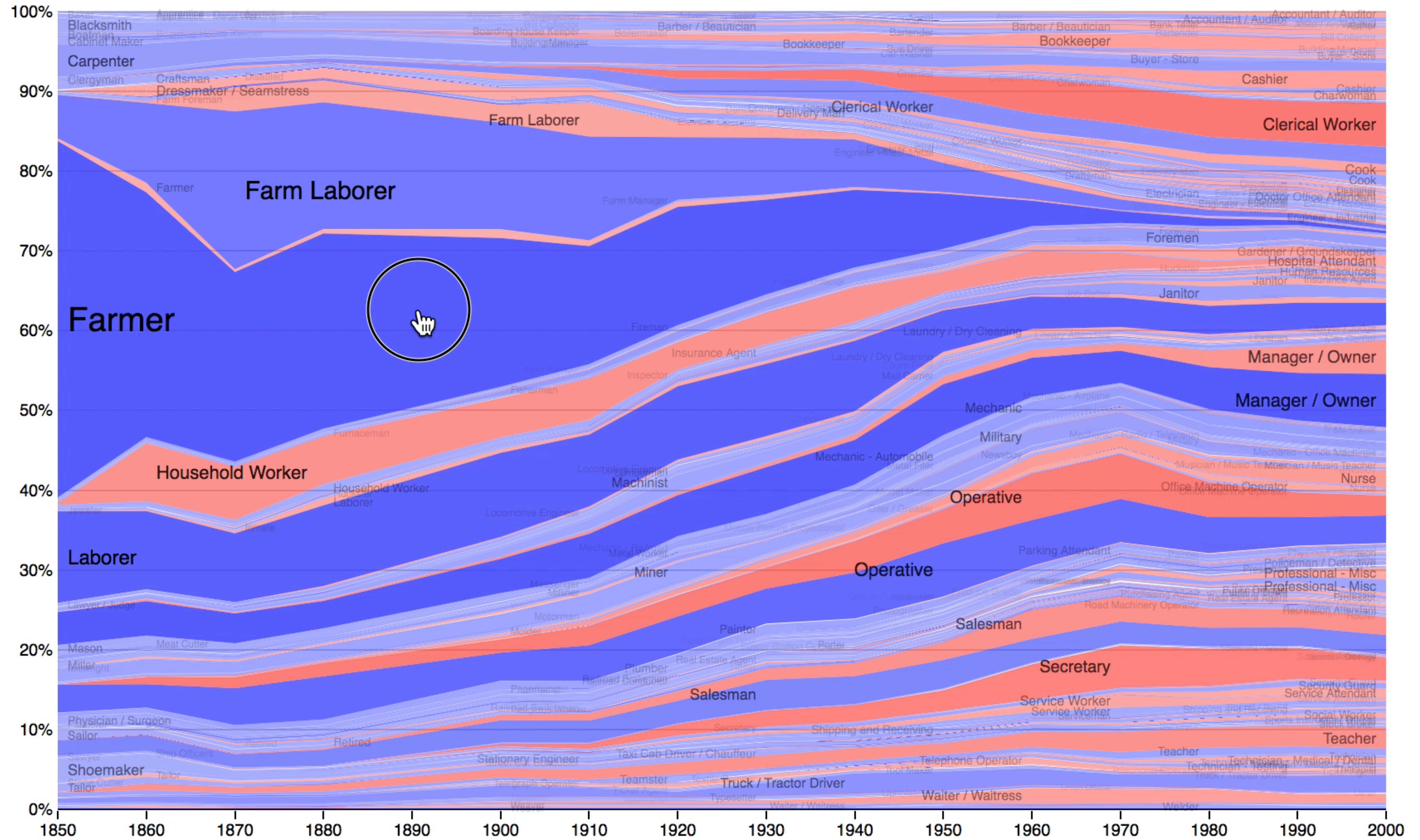




Filter

# Job Voyager

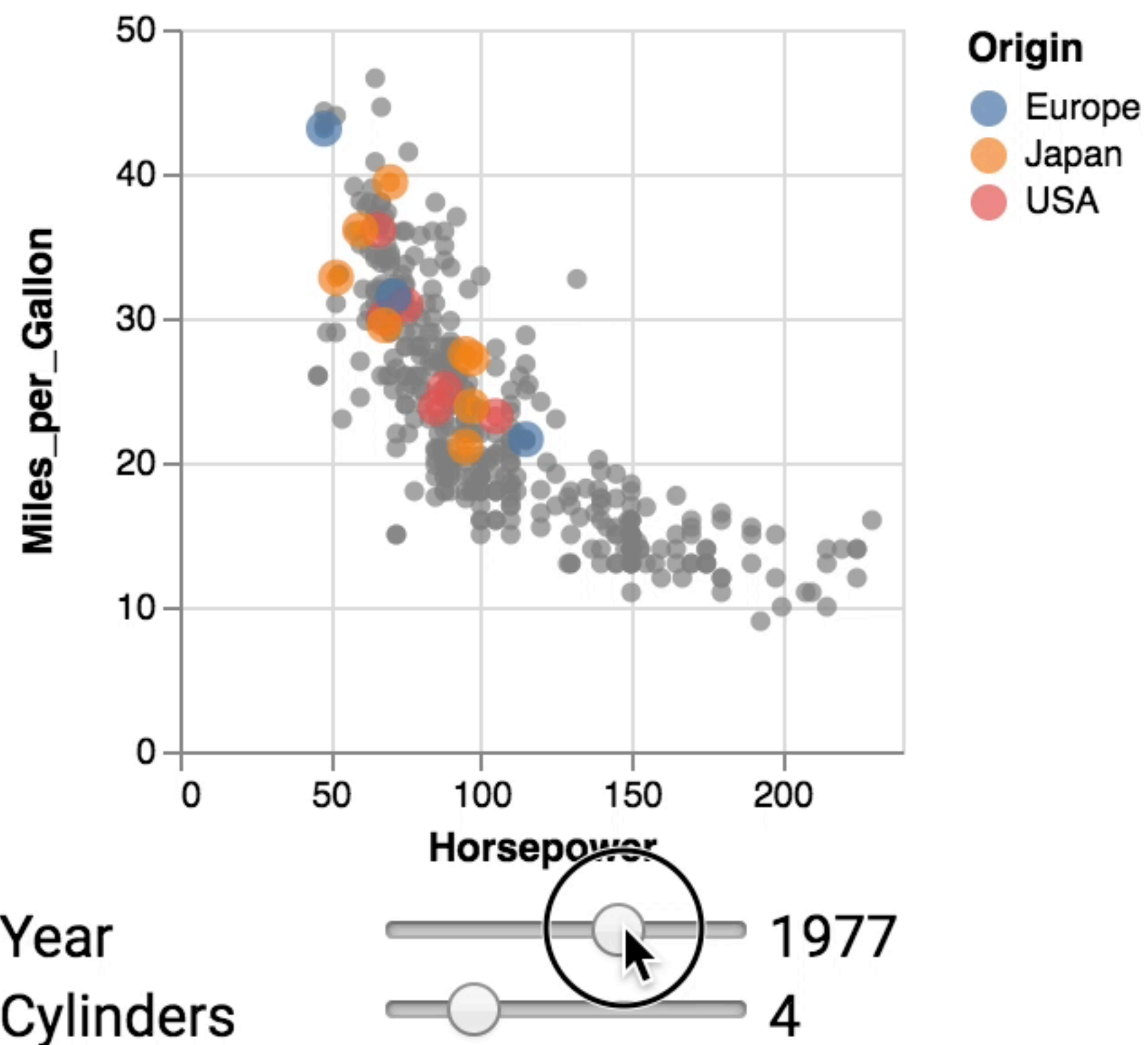
Gender:  Men  Women  Any



search: |



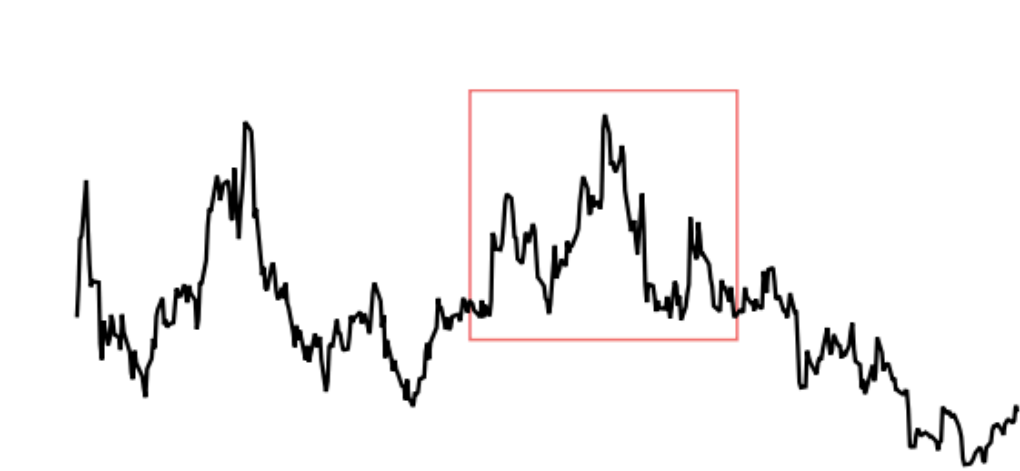
# Filter



Willet, Heer, and Agrawala. Scented Widgets. *InfoVis*, 2007.



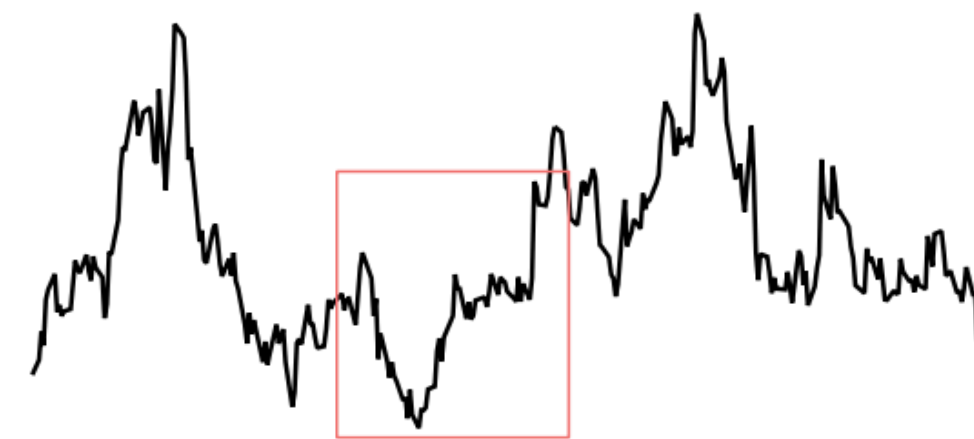




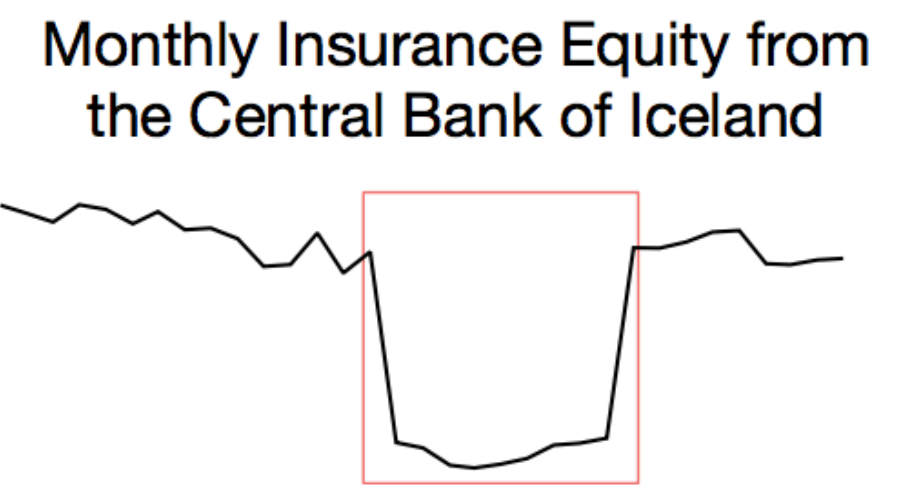
**(a) Head-and-shoulders** in Amazon stock prices, 150 days 10/99 to 3/00



**(b) Inverted head-and-shoulders** in Alaska Air Group stock prices, 108 days 08/98 to 12/98

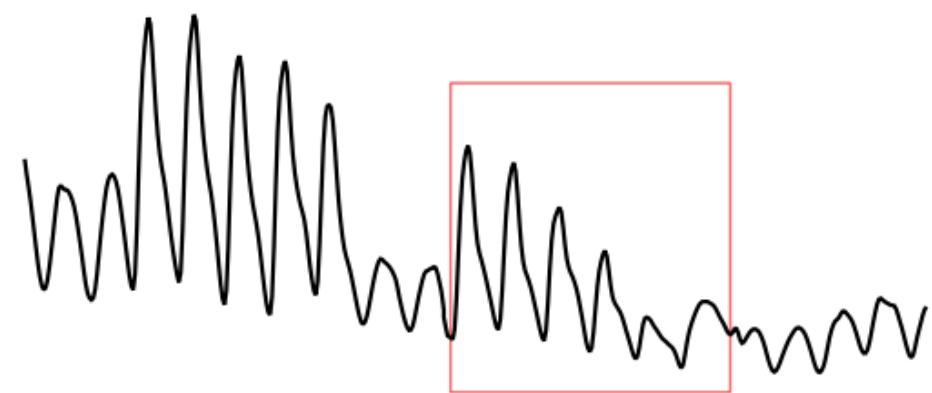


**(c) Cup-with-handle** in Amazon stock prices, 95 days 7/99 to 11/99

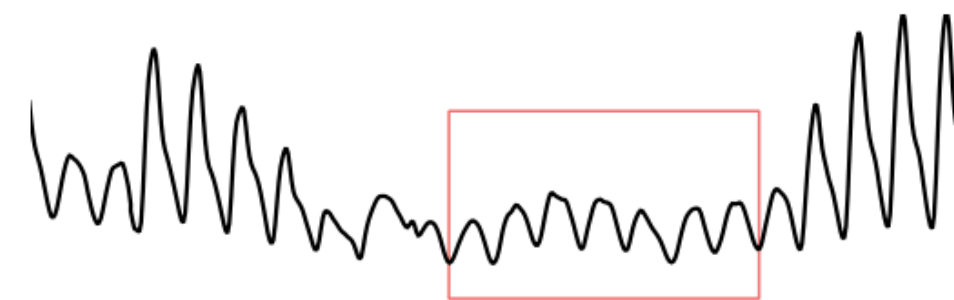


**(d) Rounded-bottom**, 304 days from 11/08 to 9/09

Hourly bit traffic in the UK academic network backbone 11/19/04 to 01/27/05

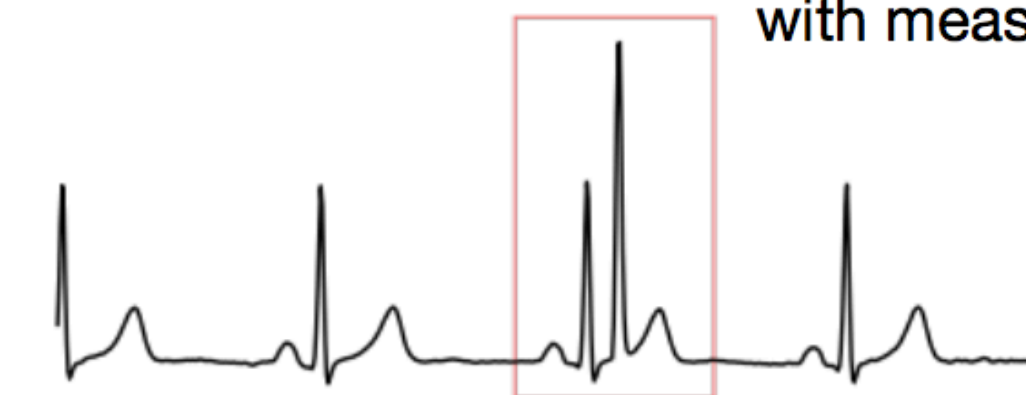


**(e) Falling peaks:** a six day decrease in traffic before 12/25/04 (Christmas)



**(f) Seven peaks:** Low traffic from 12/26/04 to 1/3/05 (Christmas to New Year's Eve)

Electrocardiograms (ECGs) from MIT-BH ST Changes, 10s data sets with measurements every 3-5ms



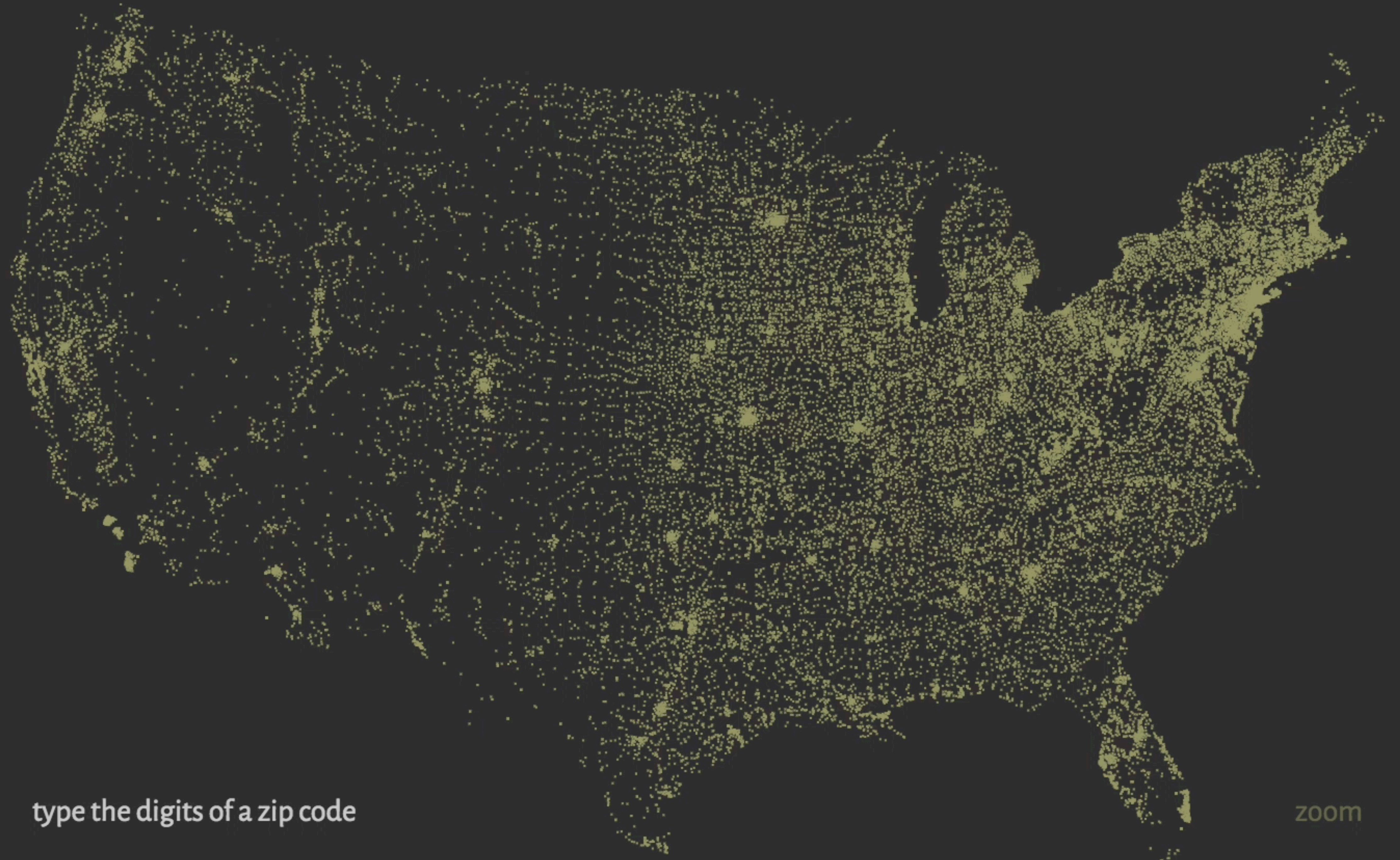
**(g) Sharp rise:** An ECG anomaly lasting 650ms in record 302



**(h) Sharp dip:** An ECG anomaly lasting 525ms in record 301

[Mannino and Abouzied. Qetch. CHI, 2018]



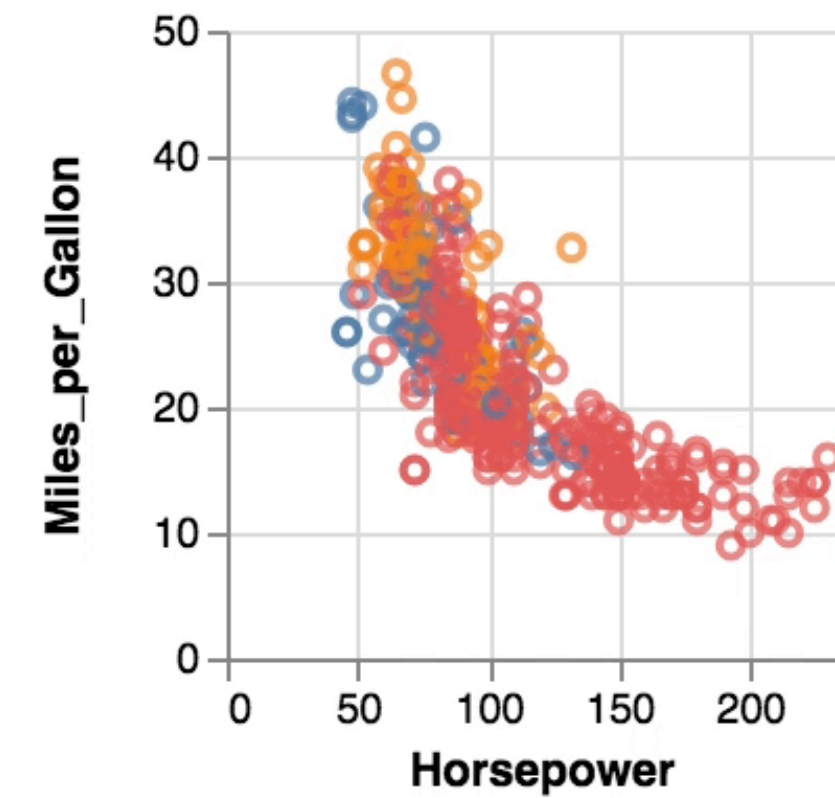
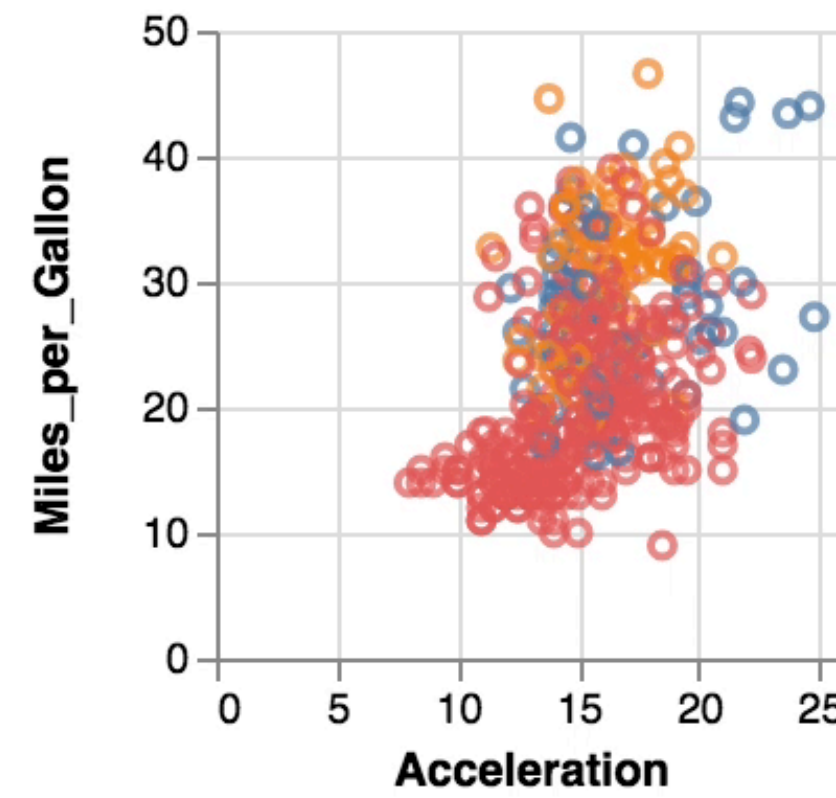
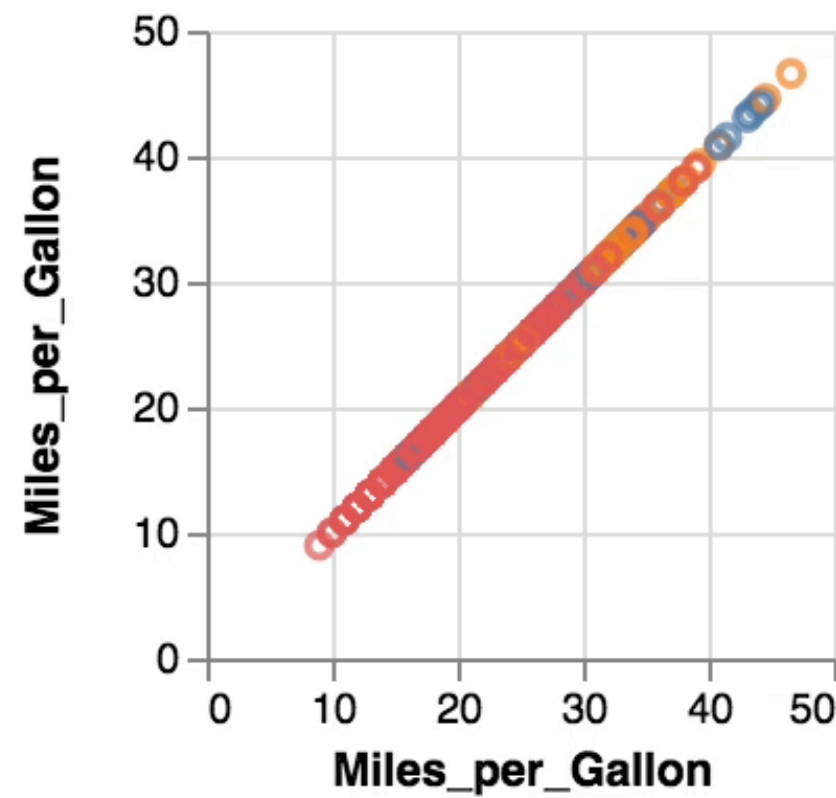
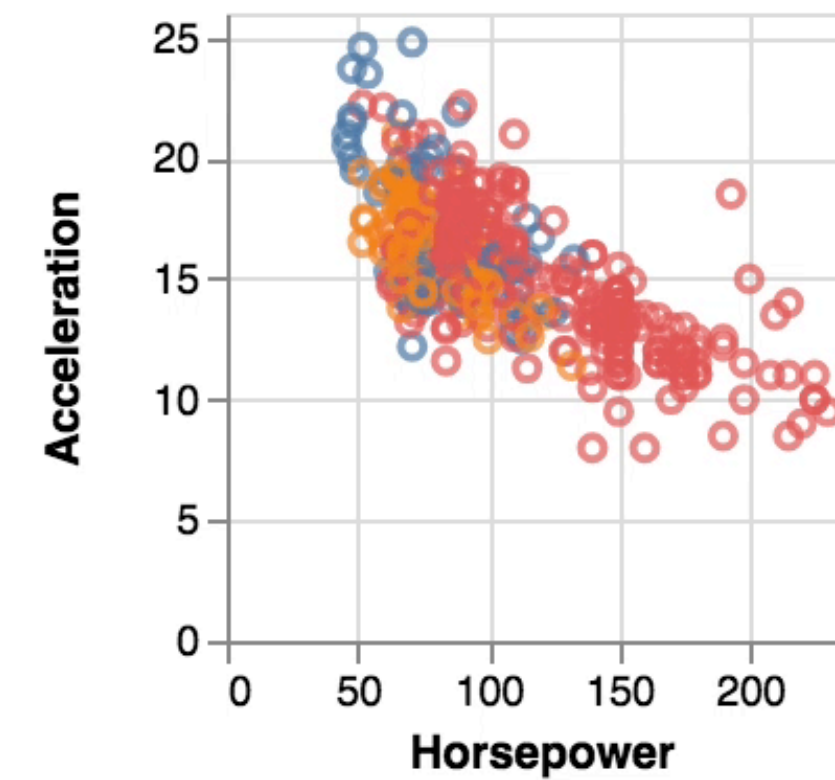
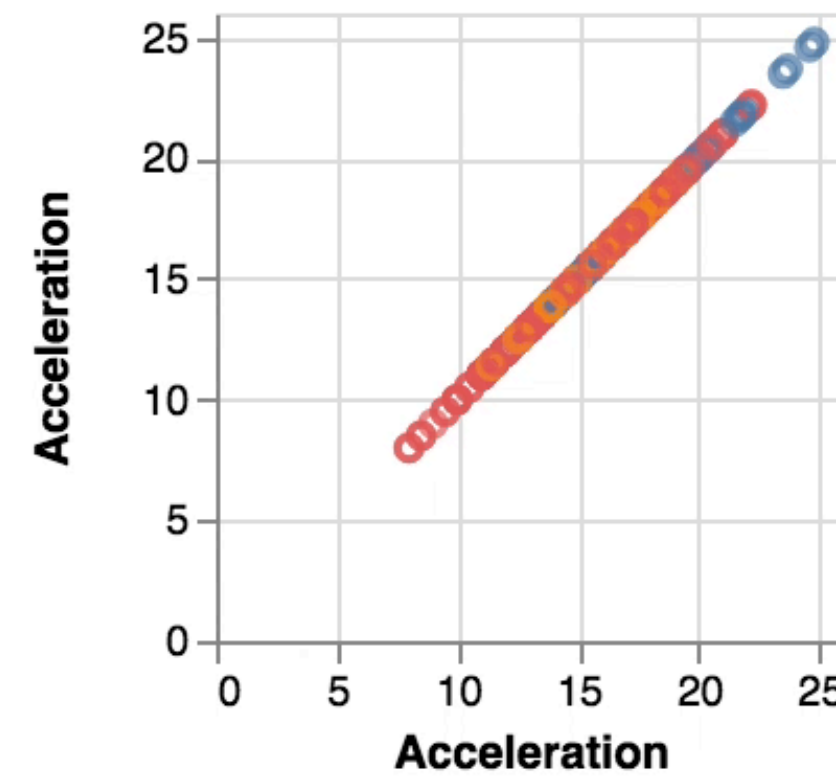
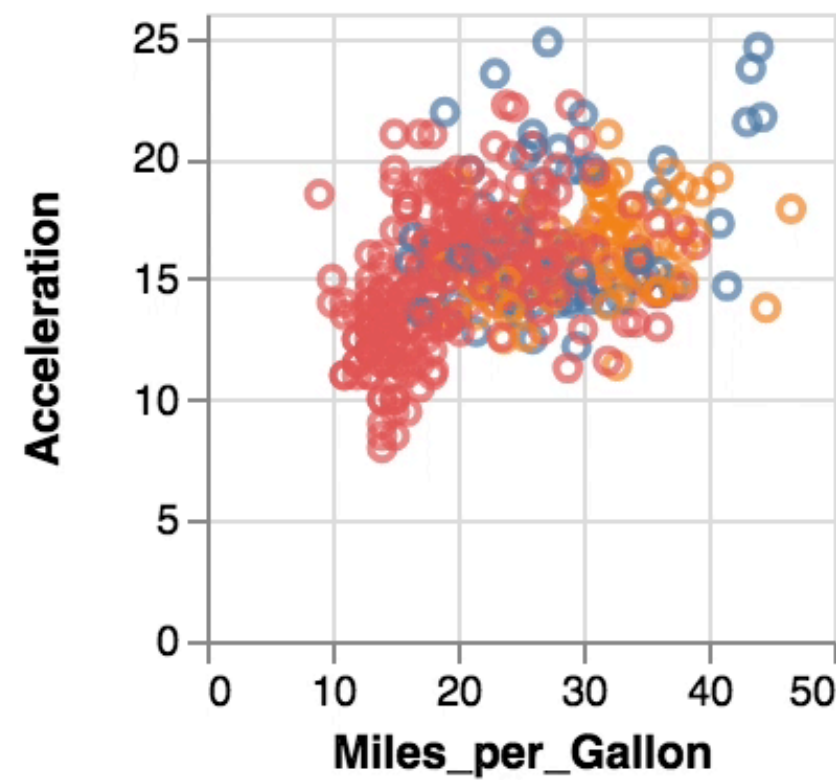
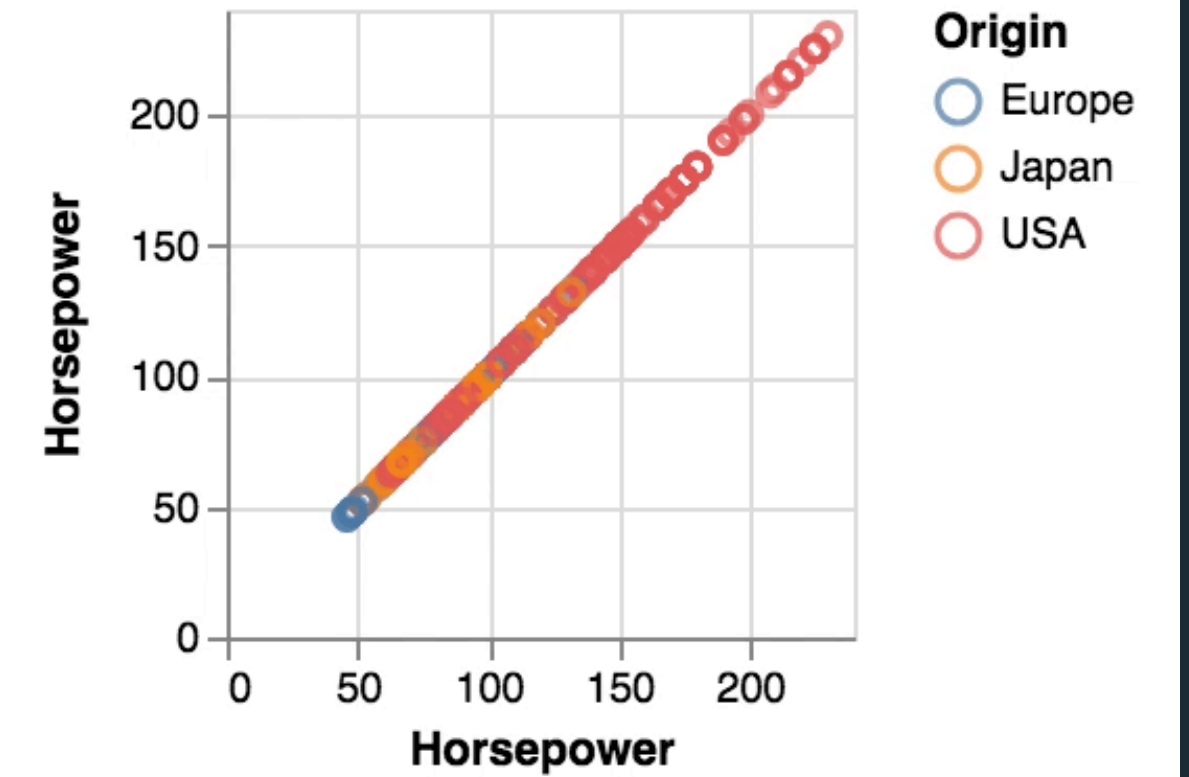
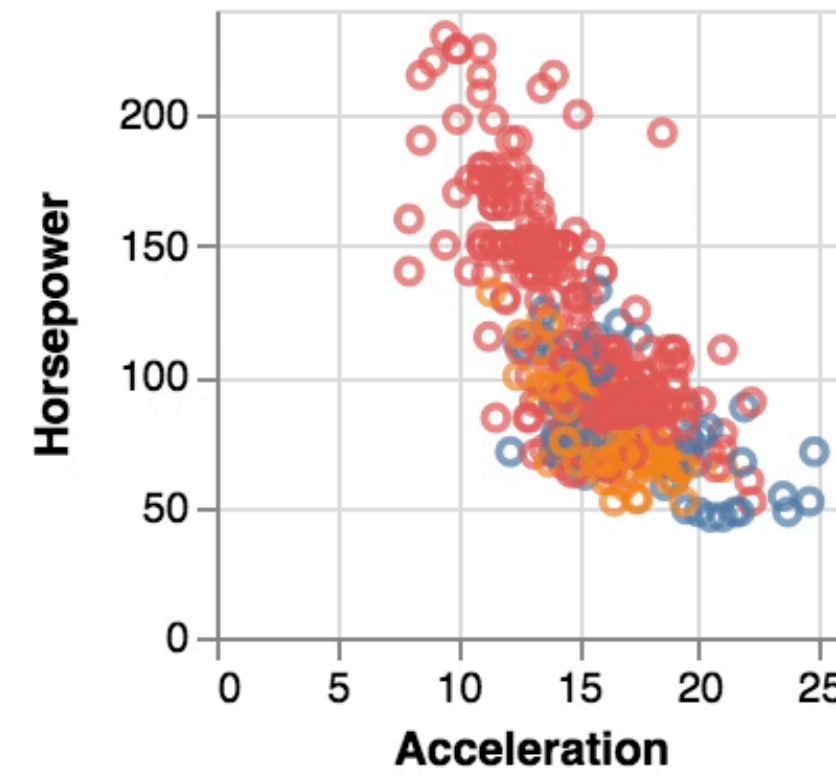
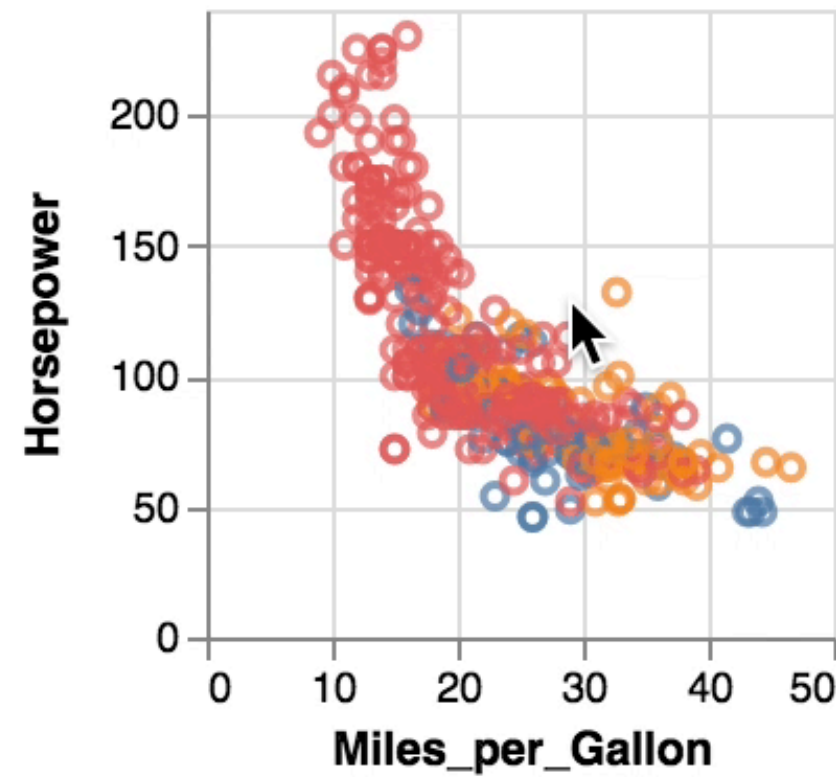
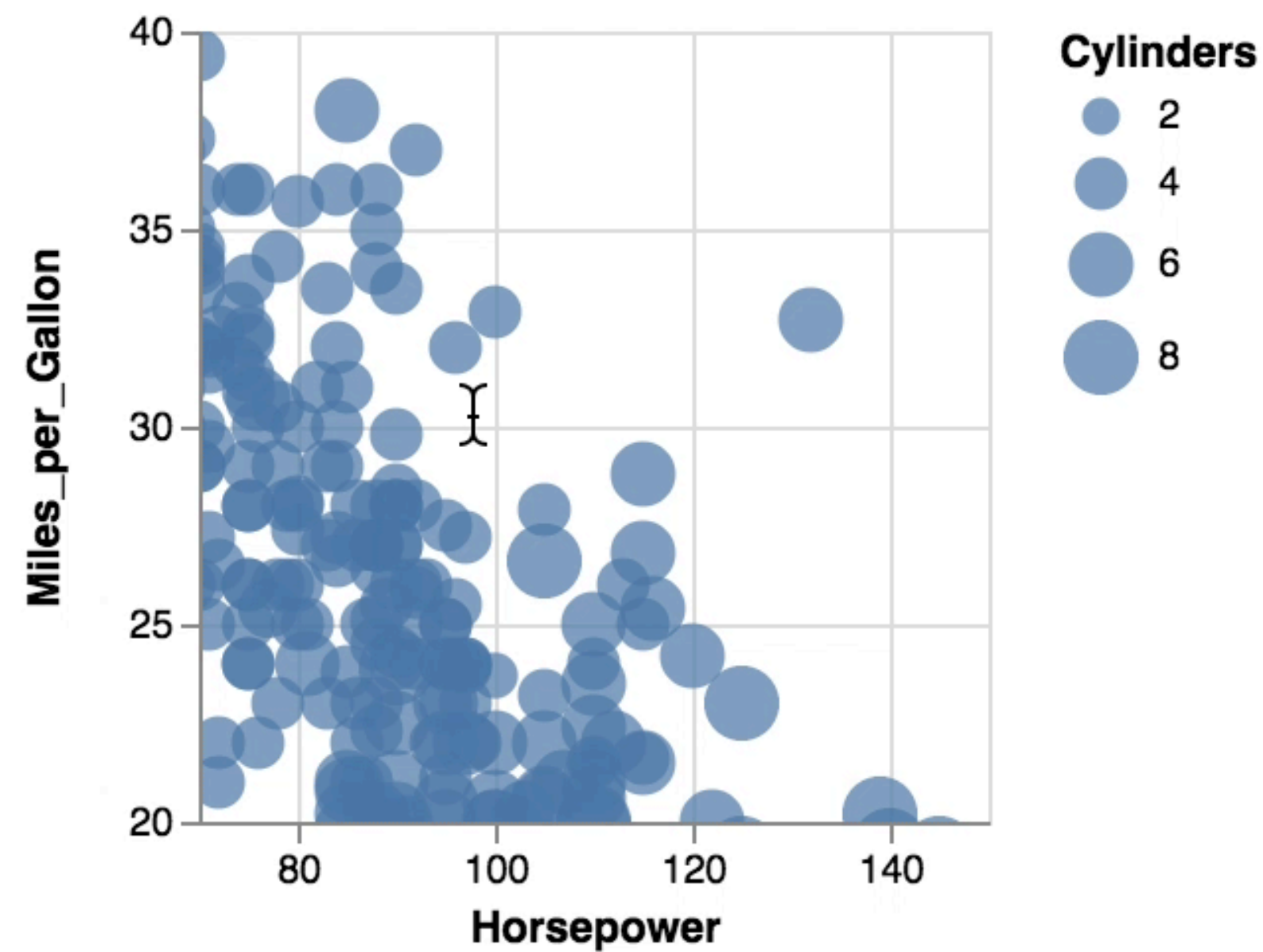


type the digits of a zip code

zoom



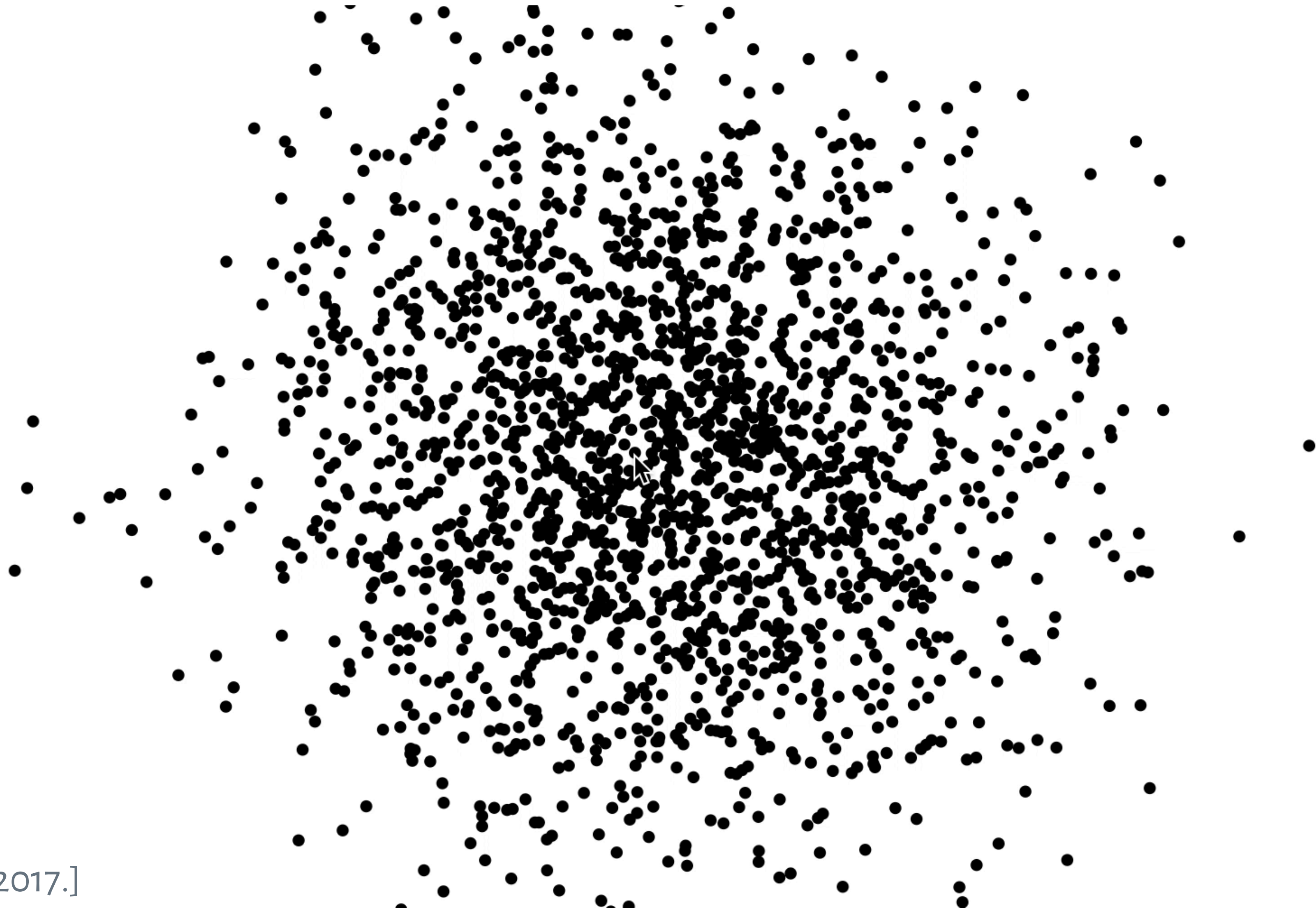
# Explore





# Explore

**Geometric** zoom: transforms the *physical view* (i.e., objects get larger as they get "closer").

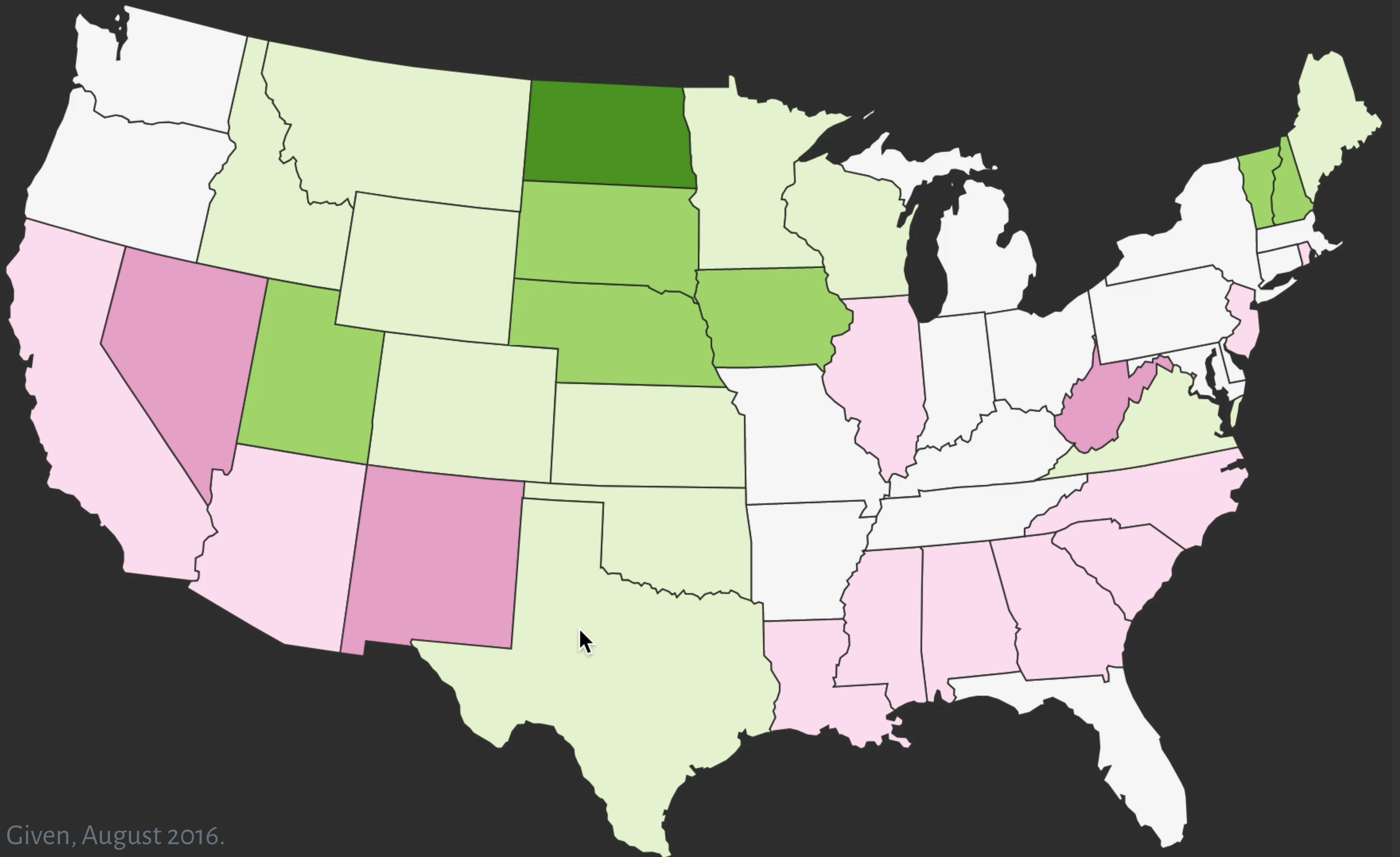


# Explore

**Semantic** zoom: transforms the *data space* (i.e., objects stay the same size, but get further apart).









# Reconfigure

[Mike Bostock. April 2012.]



Order:

This matrix diagram visualizes character co-occurrences in Victor Hugo's *Les Misérables*.

Each colored cell represents two characters that appeared in the same chapter; darker cells indicate characters that co-occurred more frequently.

Use the drop-down menu to reorder the matrix and explore the data.

Built with [d3.js](#).

Source: [The Stanford GraphBase](#).



# Reconfigure



# Reconfigure

