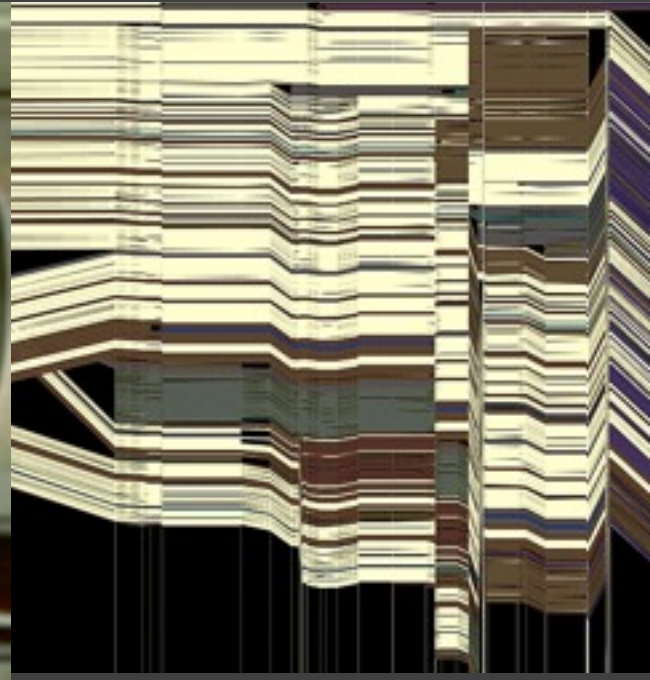
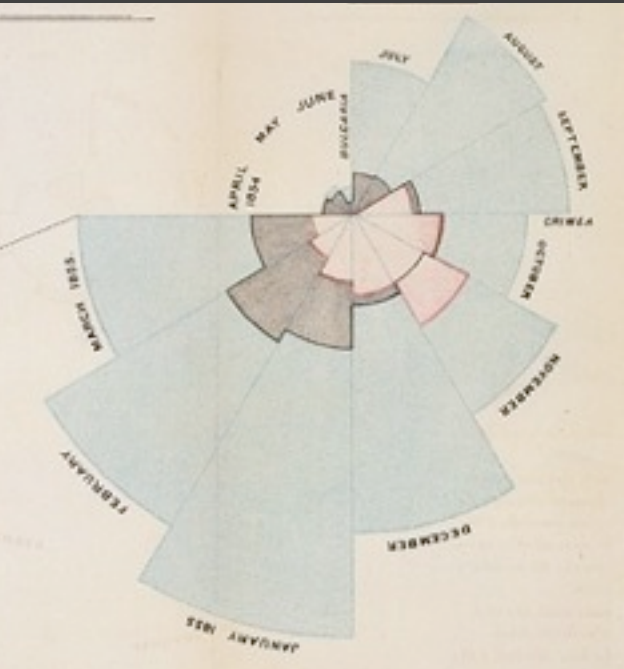


CSE512 :: 30 Jan 2014

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.

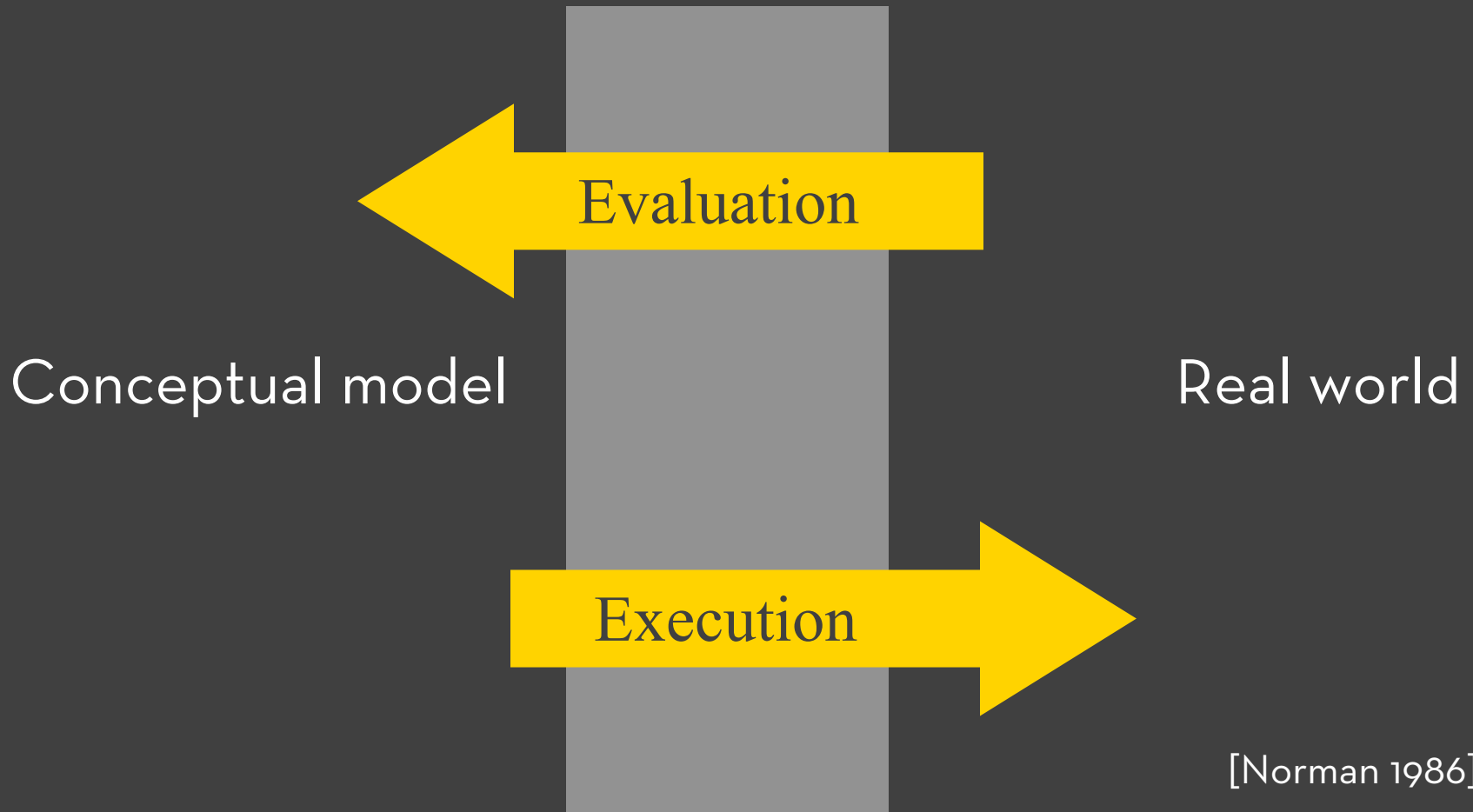
“Interaction” – in a sense previously reserved for describing a uniquely interpersonal activity – seems appropriately to characterize what goes on between people and certain machines as well.

Lucy Suchman, *Plans and Situated Actions*

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

Gulfs of Execution & Evaluation

Gulfs



[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

Evaluation

Conceptual model:
x,y correlated?

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

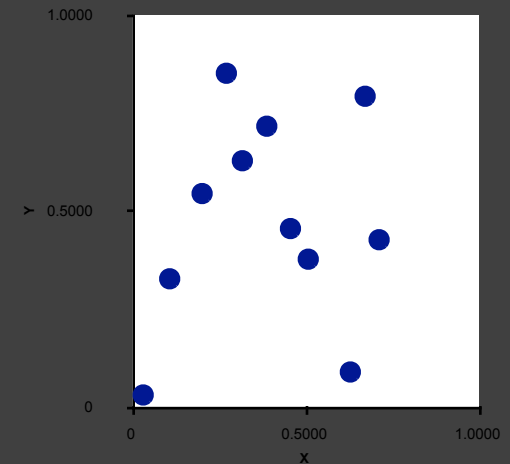
Gulf of Evaluation

Gulf



Conceptual model:
 x, y correlated?

Real world:



Gulf of Evaluation

Gulf



Conceptual model:
x,y correlated?

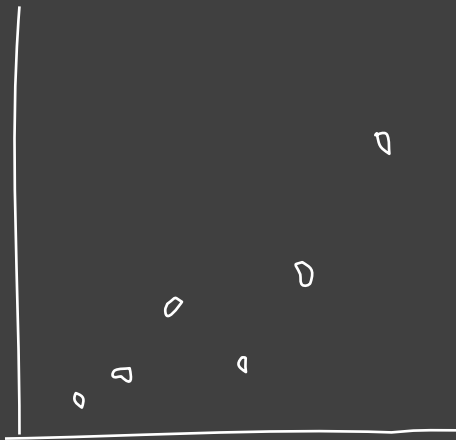
Real world:

$$\rho = -.29$$

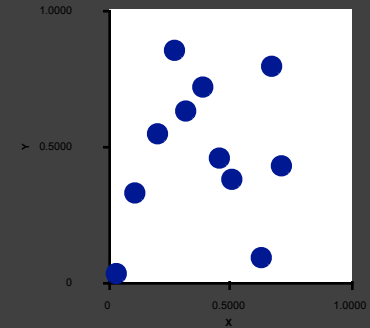
Gulf of Execution

Gulf

Conceptual model:
Draw a scatterplot



Execution



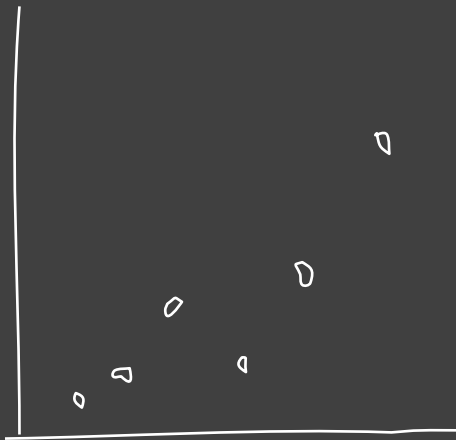
↑
Real world

Move 90 30
Rotate 35
Pen down
...

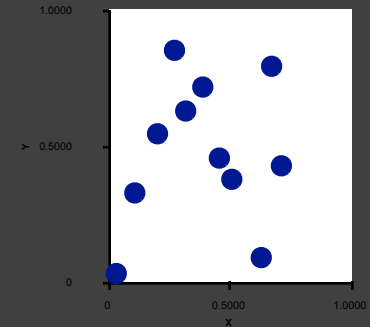
Gulf of Execution

Gulf

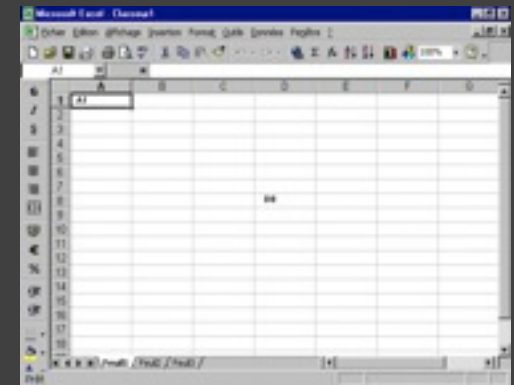
Conceptual model:
Draw a scatterplot



Execution



↑
Real world



Interaction Techniques

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

Interaction Techniques

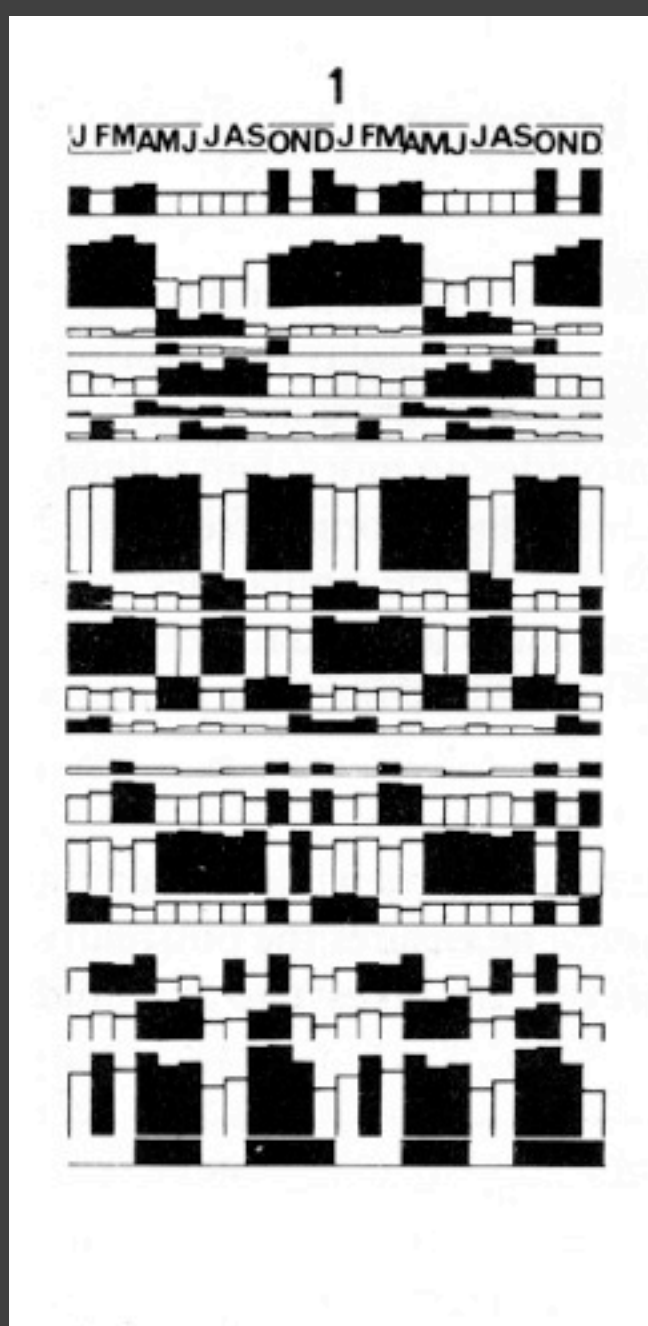
Are there “essential” interactive operations for supporting exploratory data visualization?

- View Specification (map data to visual vars)
- Navigation (pan, zoom, scale, rotate)
- Selection / Highlighting
- Filtering
- Sorting
- Extract Data

Interactive Visualization

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

[Graphics and Graphic Information Processing, Bertin 81]



[Graphics and Graphic Information Processing, Bertin 81]

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*



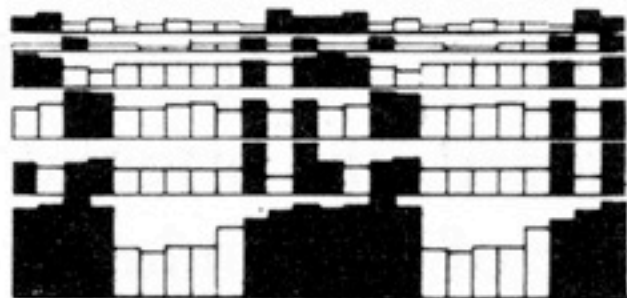
20 CONVENTIONS

8 BUSINESSMEN

11 AGENCY RESERVATIONS

4 SOUTH AMERICA

DISCOVERY FACTORS



18 AIR CREWS

18 CLIENTS UNDER 20 YEARS

10 CLIENTS MORE THAN 55 YEARS

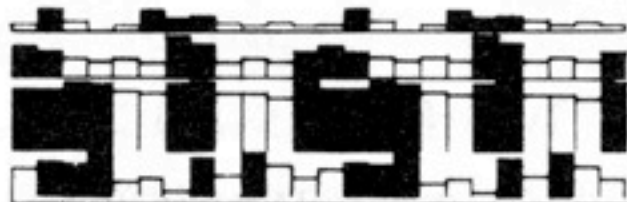
14 CLIENTS FROM 20-35 YEARS

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]



[Graphics and Graphic Information Processing, Bertin 81]



PRIM-9, Tukey, Fisherkeller, Friedman 1972

\mathcal{L}_v

1. 1991-1992	2. 1993-1994	3. 1995-1996	4. 1997-1998	5. 1999-2000	6. 2001-2002	7. 2003-2004	8. 2005-2006	9. 2007-2008	10. 2009-2010	11. 2011-2012	12. 2013-2014	13. 2015-2016	14. 2017-2018	15. 2019-2020	16. 2021-2022	17. 2023-2024	18. 2025-2026	19. 2027-2028	20. 2029-2030	21. 2031-2032	22. 2033-2034	23. 2035-2036	24. 2037-2038	25. 2039-2040	26. 2041-2042	27. 2043-2044	28. 2045-2046	29. 2047-2048	30. 2049-2050	31. 2051-2052	32. 2053-2054	33. 2055-2056	34. 2057-2058	35. 2059-2060	36. 2061-2062	37. 2063-2064	38. 2065-2066	39. 2067-2068	40. 2069-2070	41. 2071-2072	42. 2073-2074	43. 2075-2076	44. 2077-2078	45. 2079-2080	46. 2081-2082	47. 2083-2084	48. 2085-2086	49. 2087-2088	50. 2089-2090	51. 2091-2092	52. 2093-2094	53. 2095-2096	54. 2097-2098	55. 2099-2100	56. 2101-2102	57. 2103-2104	58. 2105-2106	59. 2107-2108	60. 2109-2110	61. 2111-2112	62. 2113-2114	63. 2115-2116	64. 2117-2118	65. 2119-2120	66. 2121-2122	67. 2123-2124	68. 2125-2126	69. 2127-2128	70. 2129-2130	71. 2131-2132	72. 2133-2134	73. 2135-2136	74. 2137-2138	75. 2139-2140	76. 2141-2142	77. 2143-2144	78. 2145-2146	79. 2147-2148	80. 2149-2150	81. 2151-2152	82. 2153-2154	83. 2155-2156	84. 2157-2158	85. 2159-2160	86. 2161-2162	87. 2163-2164	88. 2165-2166	89. 2167-2168	90. 2169-2170	91. 2171-2172	92. 2173-2174	93. 2175-2176	94. 2177-2178	95. 2179-2180	96. 2181-2182	97. 2183-2184	98. 2185-2186	99. 2187-2188	100. 2189-2190	101. 2191-2192	102. 2193-2194	103. 2195-2196	104. 2197-2198	105. 2199-2200	106. 2201-2202	107. 2203-2204	108. 2205-2206	109. 2207-2208	110. 2209-2210	111. 2211-2212	112. 2213-2214	113. 2215-2216	114. 2217-2218	115. 2219-2220	116. 2221-2222	117. 2223-2224	118. 2225-2226	119. 2227-2228	120. 2229-2230	121. 2231-2232	122. 2233-2234	123. 2235-2236	124. 2237-2238	125. 2239-2240	126. 2241-2242	127. 2243-2244	128. 2245-2246	129. 2247-2248	130. 2249-2250	131. 2251-2252	132. 2253-2254	133. 2255-2256	134. 2257-2258	135. 2259-2260	136. 2261-2262	137. 2263-2264	138. 2265-2266	139. 2267-2268	140. 2269-2270	141. 2271-2272	142. 2273-2274	143. 2275-2276	144. 2277-2278	145. 2279-2280	146. 2281-2282	147. 2283-2284	148. 2285-2286	149. 2287-2288	150. 2289-2290	151. 2291-2292	152. 2293-2294	153. 2295-2296	154. 2297-2298	155. 2299-2300	156. 2301-2302	157. 2303-2304	158. 2305-2306	159. 2307-2308	160. 2309-2310	161. 2311-2312	162. 2313-2314	163. 2315-2316	164. 2317-2318	165. 2319-2320	166. 2321-2322	167. 2323-2324	168. 2325-2326	169. 2327-2328	170. 2329-2330	171. 2331-2332	172. 2333-2334	173. 2335-2336	174. 2337-2338	175. 2339-2340	176. 2341-2342	177. 2343-2344	178. 2345-2346	179. 2347-2348	180. 2349-2350	181. 2351-2352	182. 2353-2354	183. 2355-2356	184. 2357-2358	185. 2359-2360	186. 2361-2362	187. 2363-2364	188. 2365-2366	189. 2367-2368	190. 2369-2370	191. 2371-2372	192. 2373-2374	193. 2375-2376	194. 2377-2378	195. 2379-2380	196. 2381-2382	197. 2383-2384	198. 2385-2386	199. 2387-2388	200. 2389-2390	201. 2391-2392	202. 2393-2394	203. 2395-2396	204. 2397-2398	205. 2399-2400	206. 2401-2402	207. 2403-2404	208. 2405-2406	209. 2407-2408	210. 2409-
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Pointing

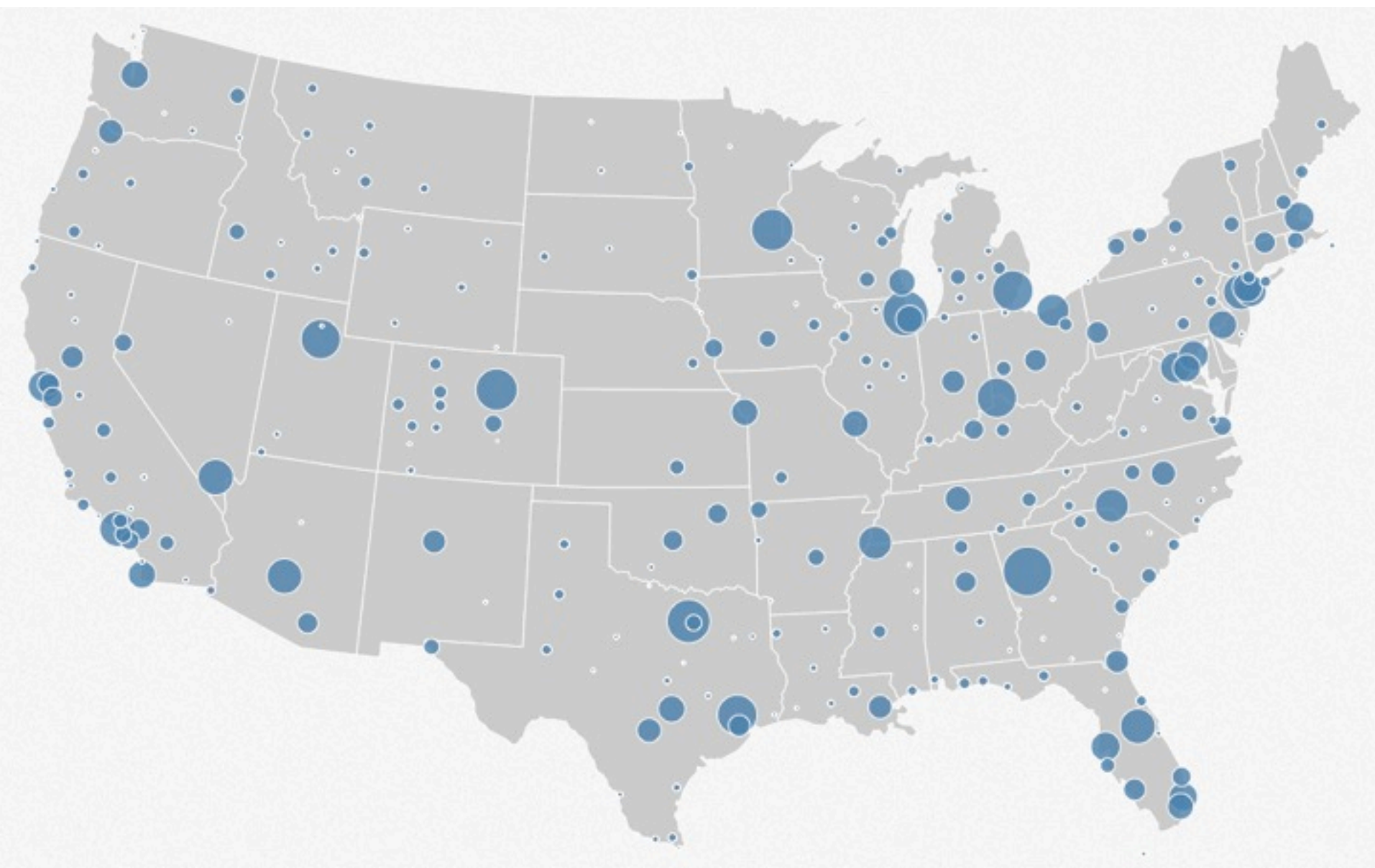
Basic Pointing Methods

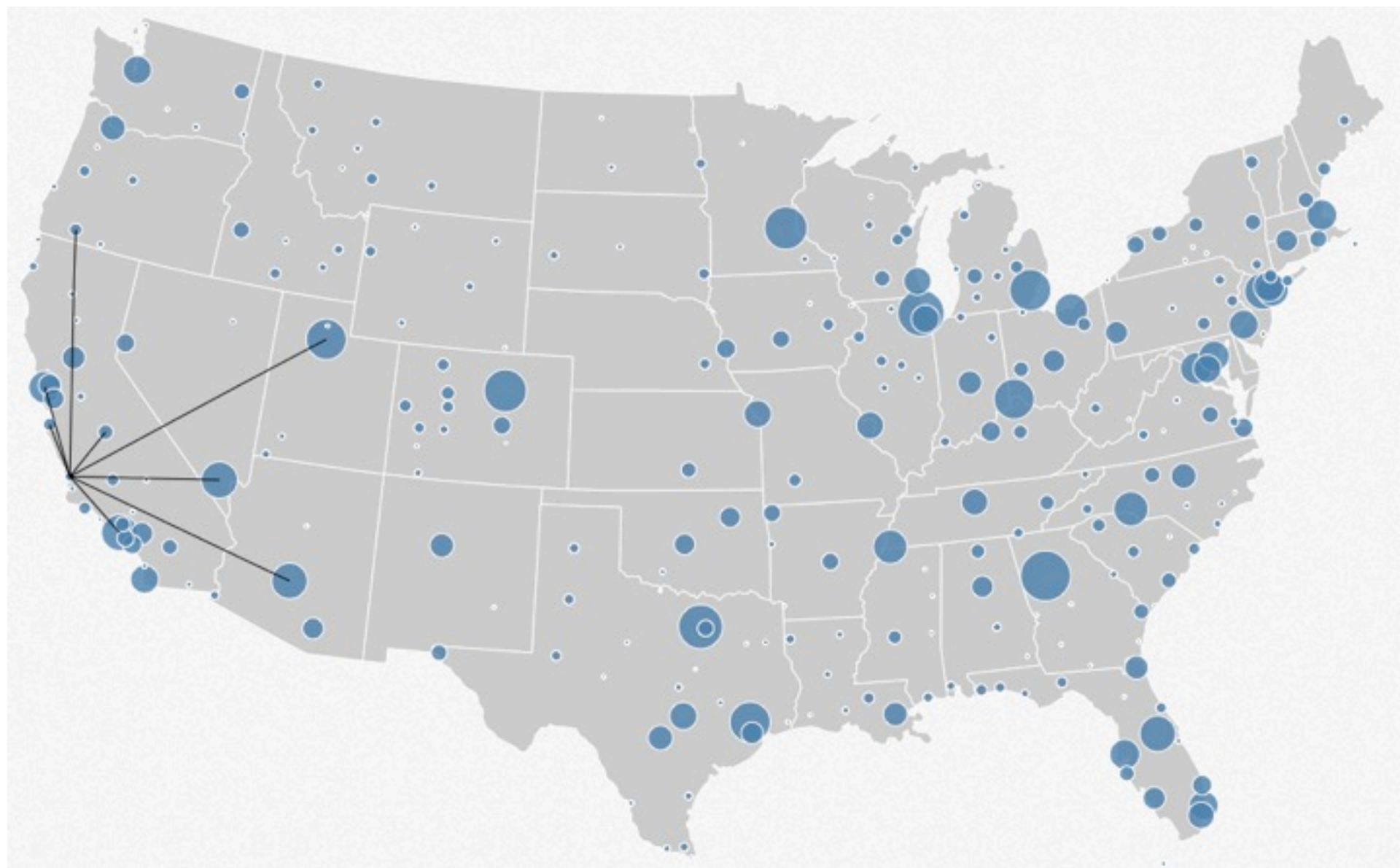
Point Selection

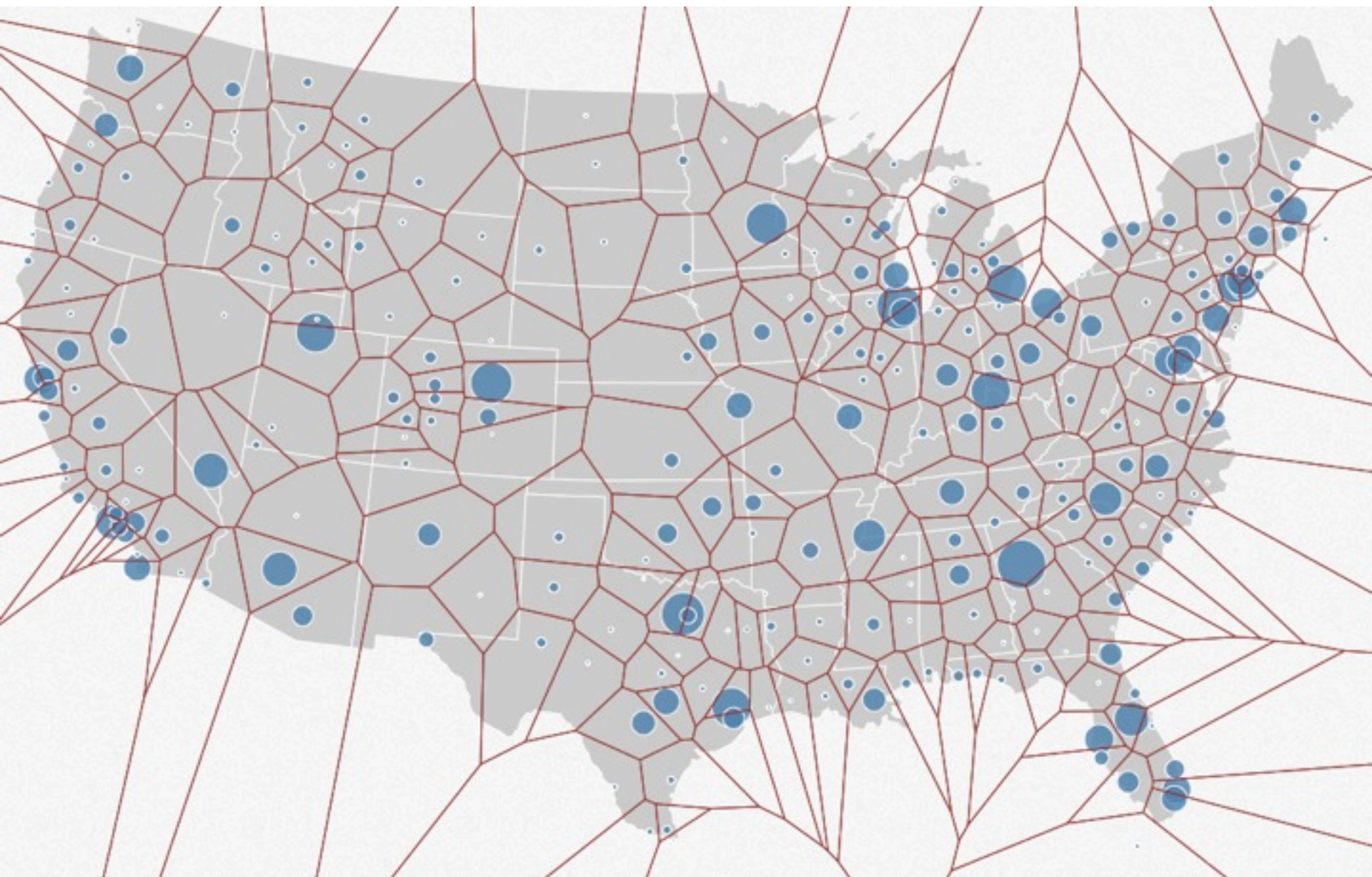
Mouse Hover / Click

Touch / Tap

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







Basic Pointing Methods

Point Selection

Mouse Hover / Click

Touch / Tap

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

Region Selection

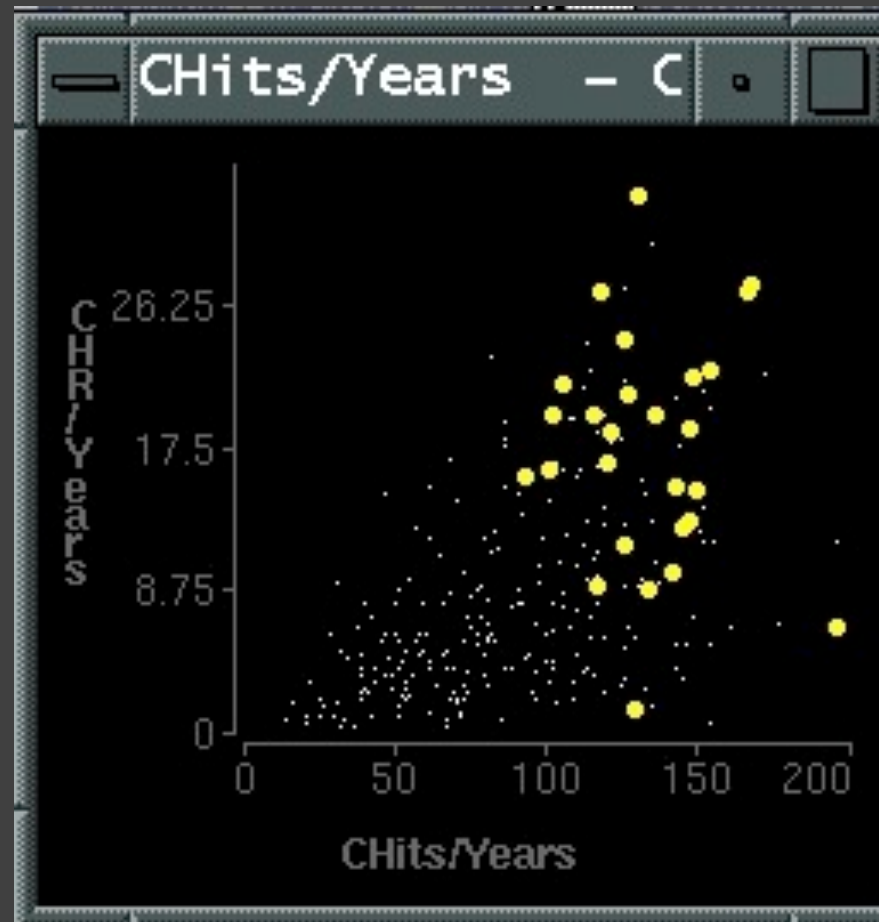
Rubber-band or Lasso

Area Cursors (“Brushes”)

Brushing and Linking

Highlighting / Brushing

Direct attention to a data subset within a graph [Wills 95]



Brushing and Linking

Select (“brush”) a subset of data

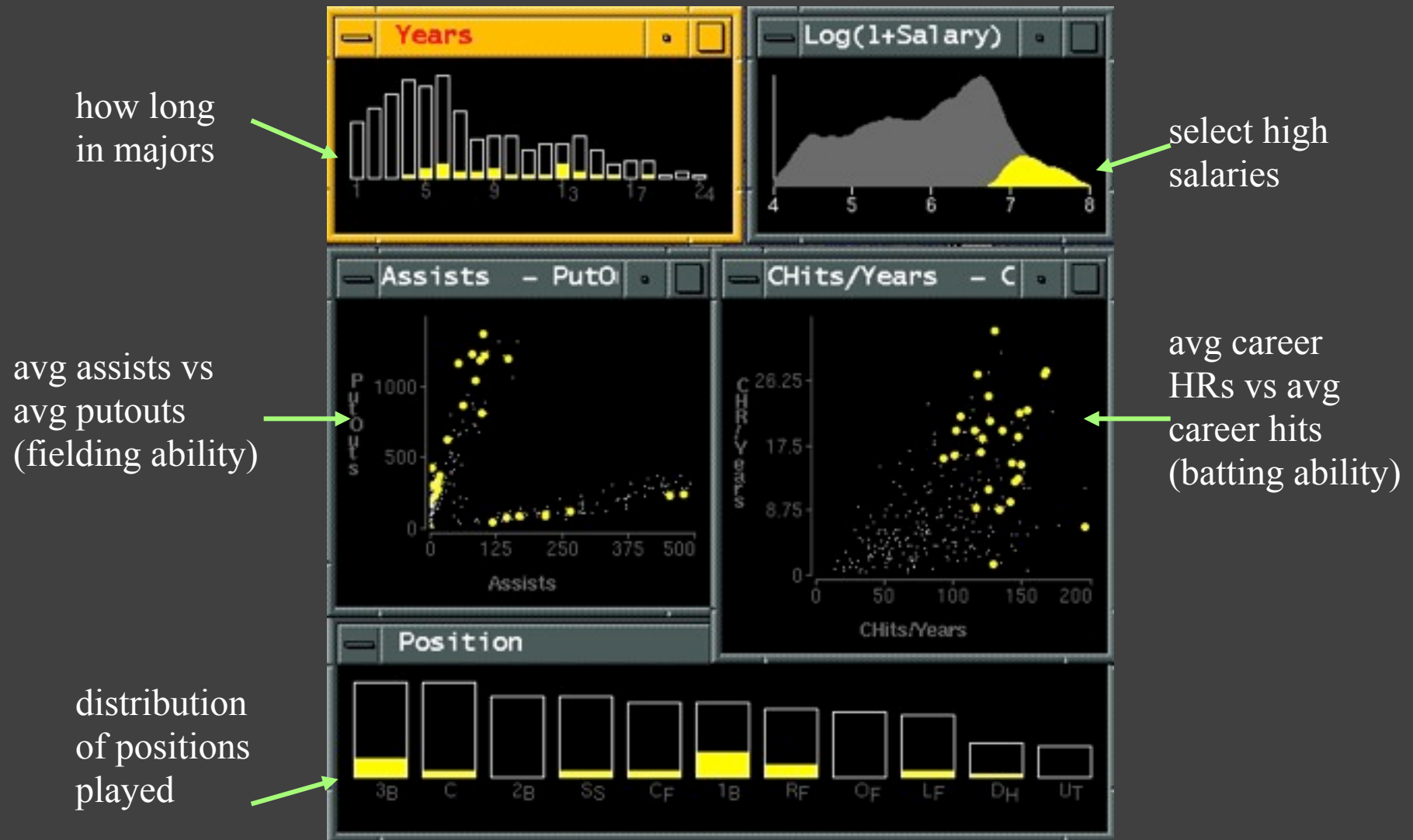
See selected data in other views

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

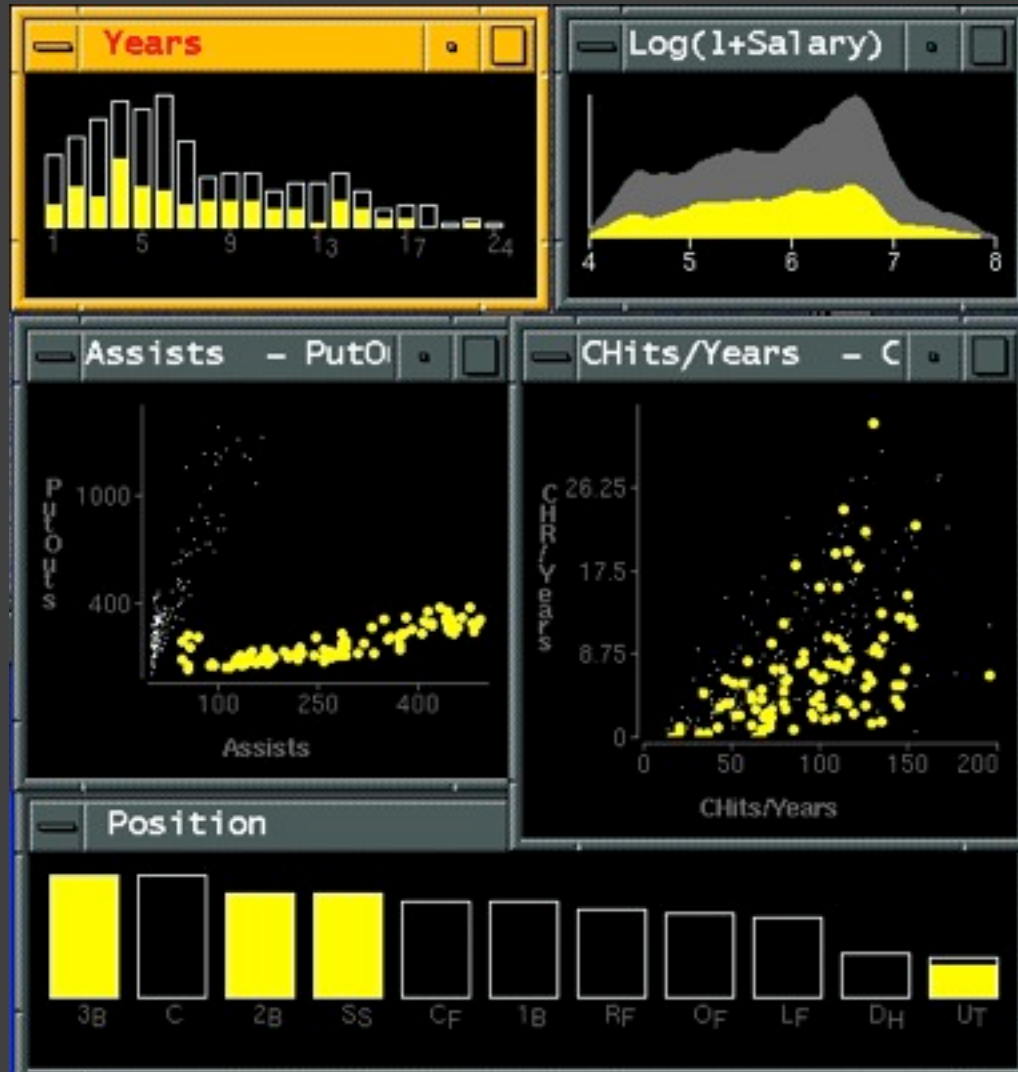


Brushing Scatterplots, Becker & Cleveland 1982

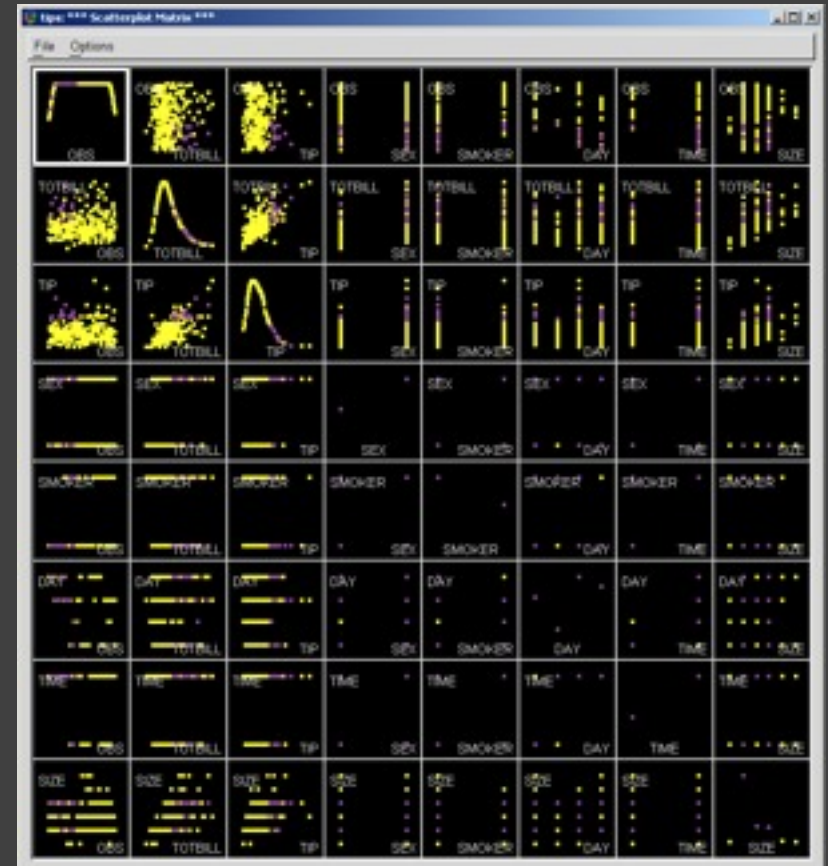
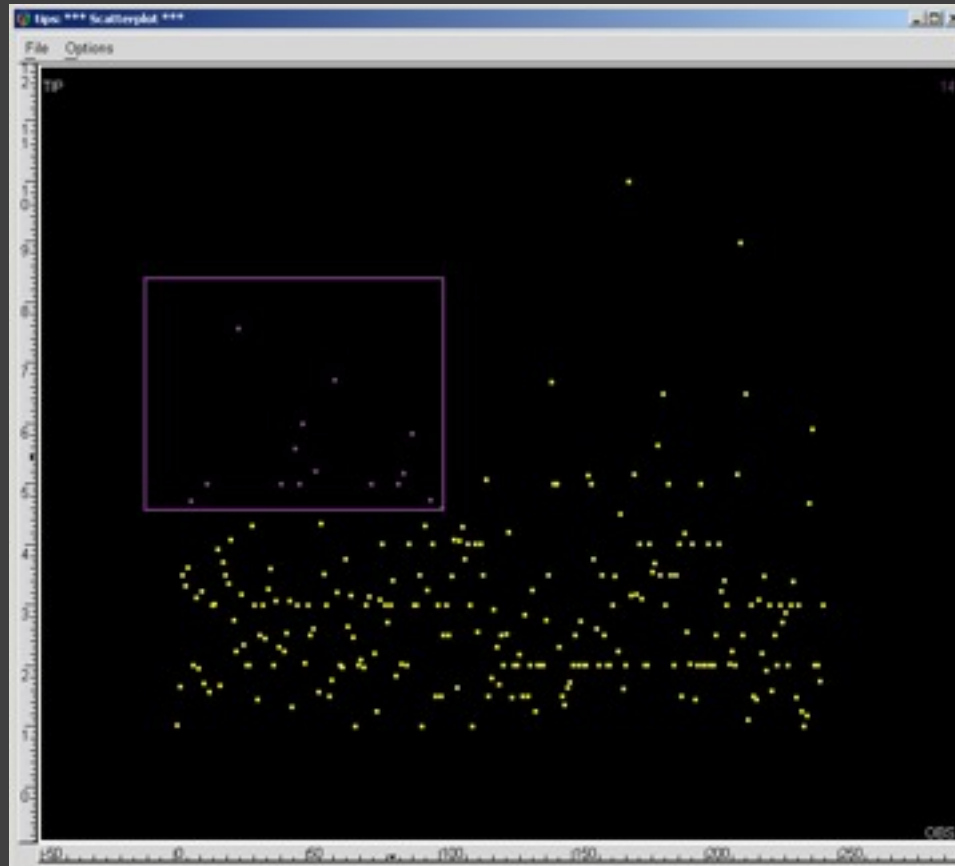
Baseball Statistics [from Wills 95]



Linking Assists to Positions



GGobi: Brushing



<http://www.ggobi.org/>

Dynamic Queries

Query and Results

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

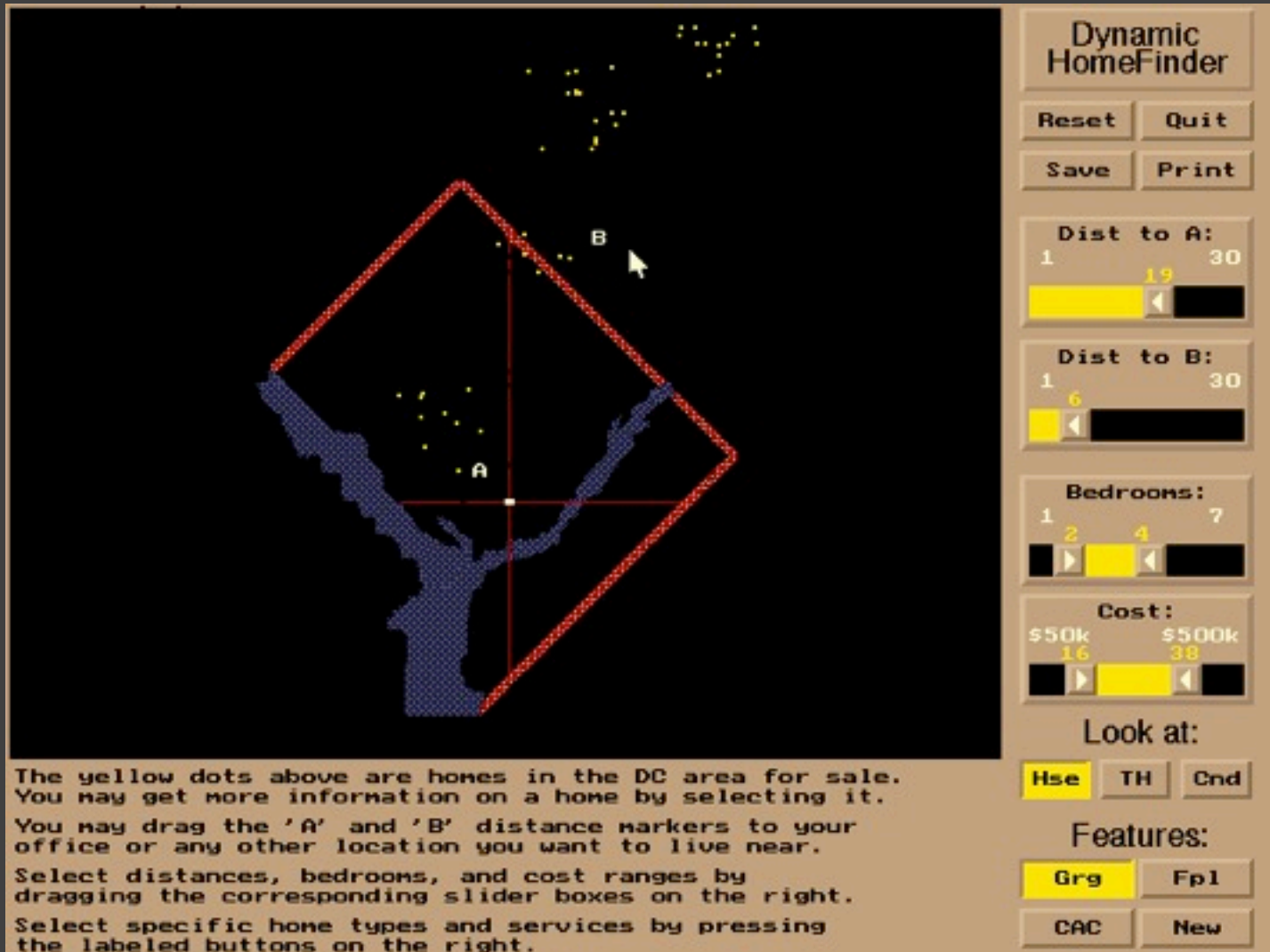
Dynamic Browser : DC Home Finder

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

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

HomeFinder

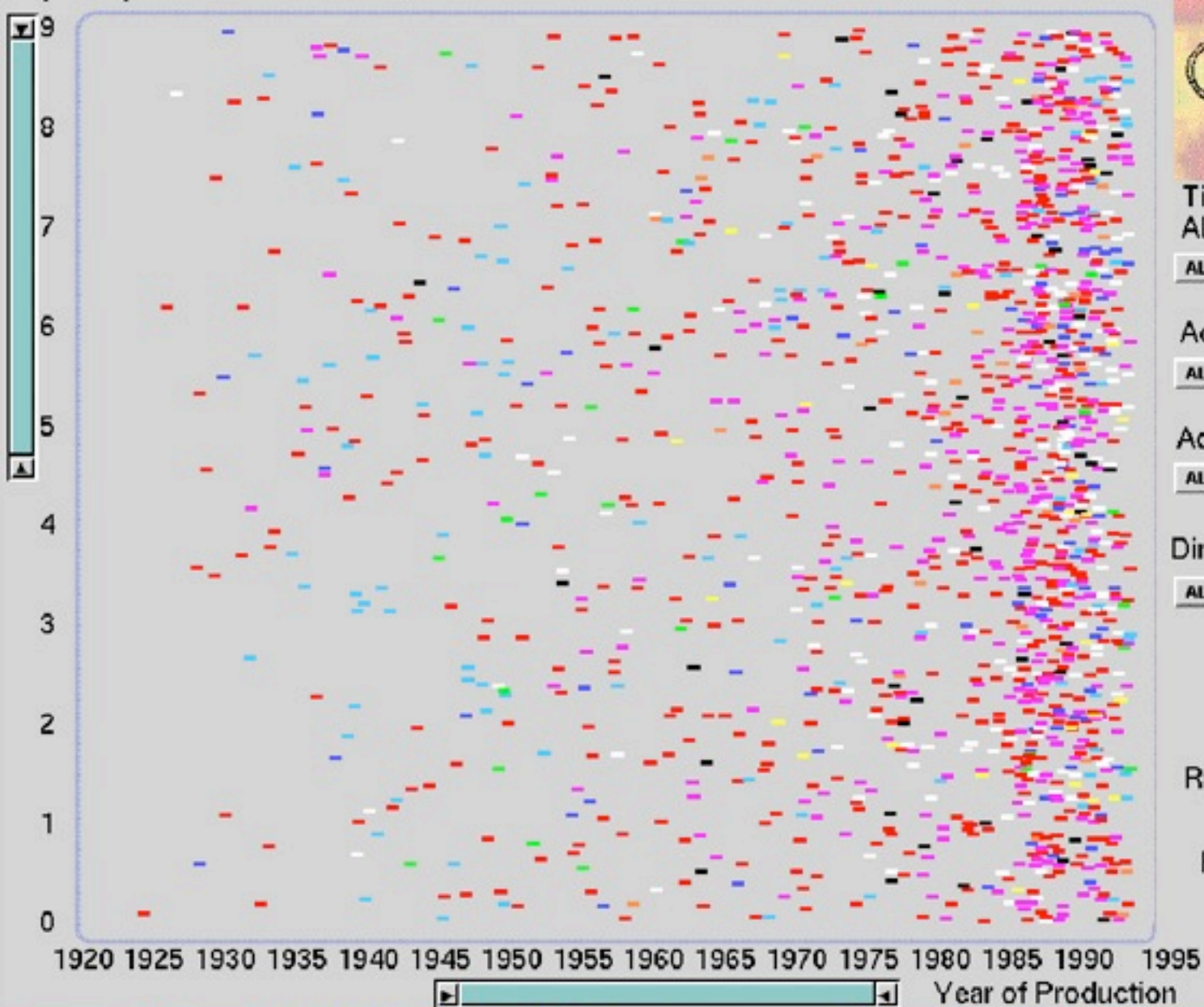


[Williamson and Shneiderman 92]

Direct Manipulation

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

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

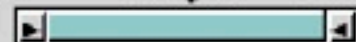
A B C D F G H K L M P R S T W Z

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

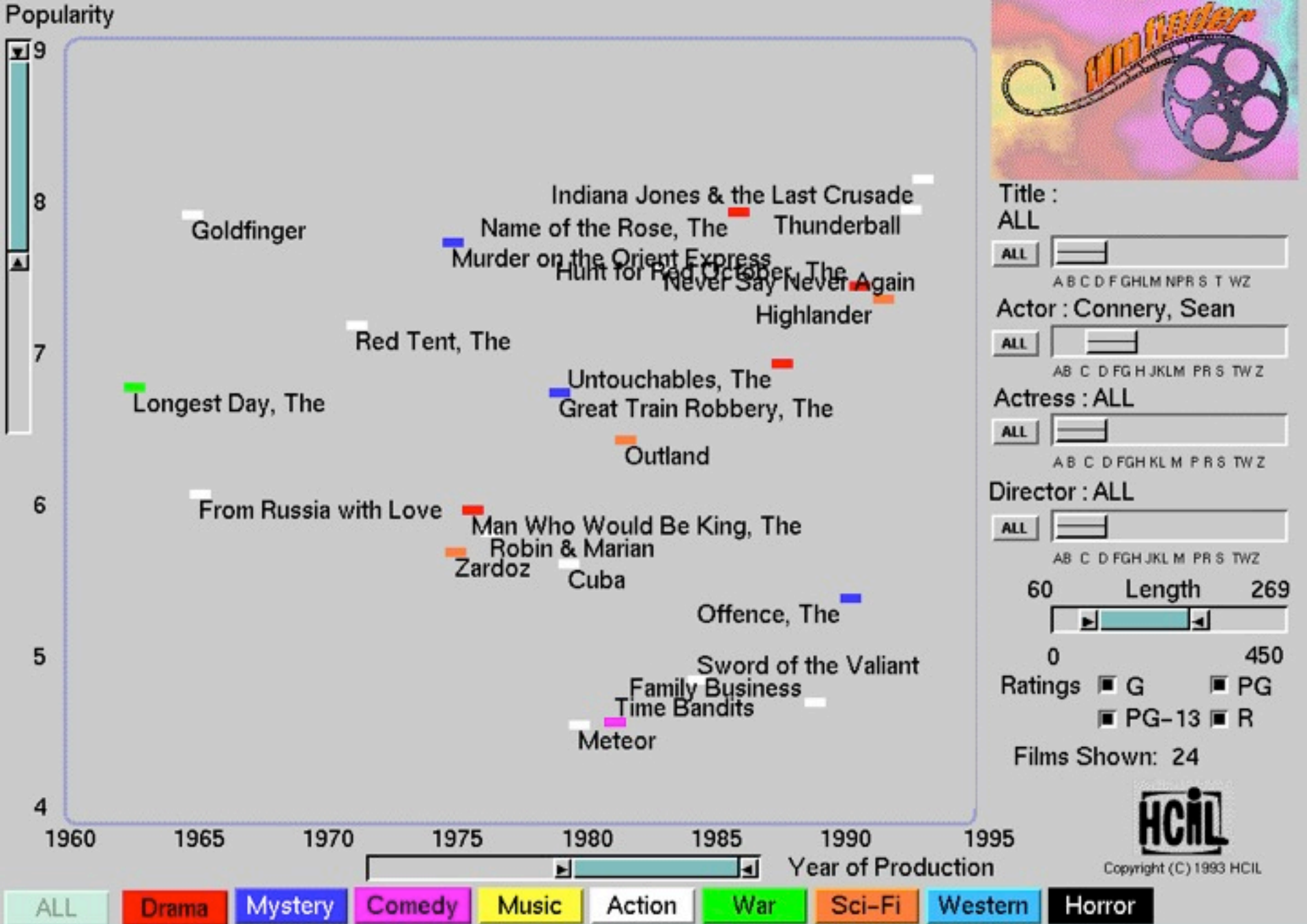
War

Sci-Fi

Western

Horror

[Ahlberg and Shneiderman 94]

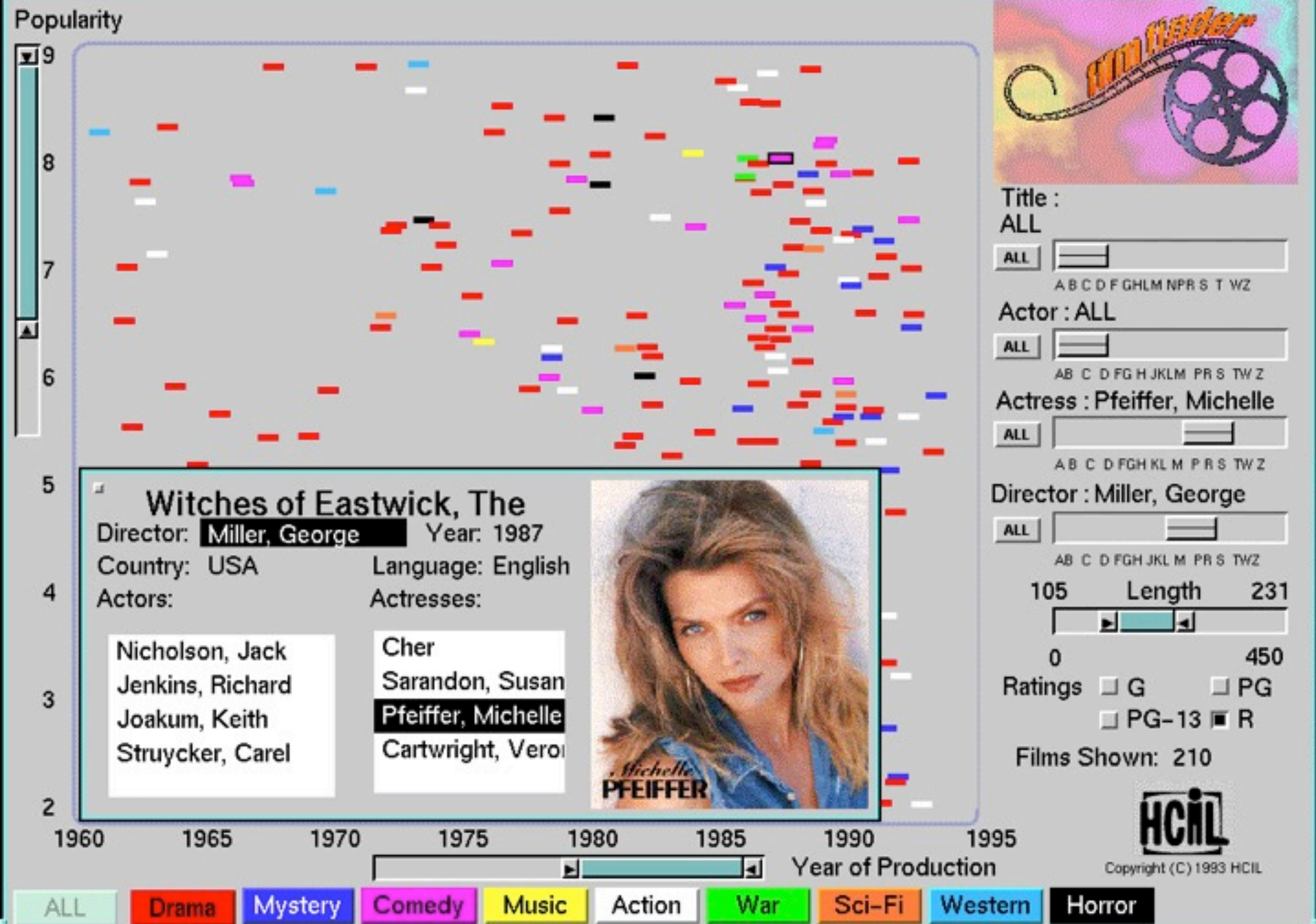


[Ahlberg and Shneiderman 94]

Alphaslider



[Ahlberg and Shneiderman 94]



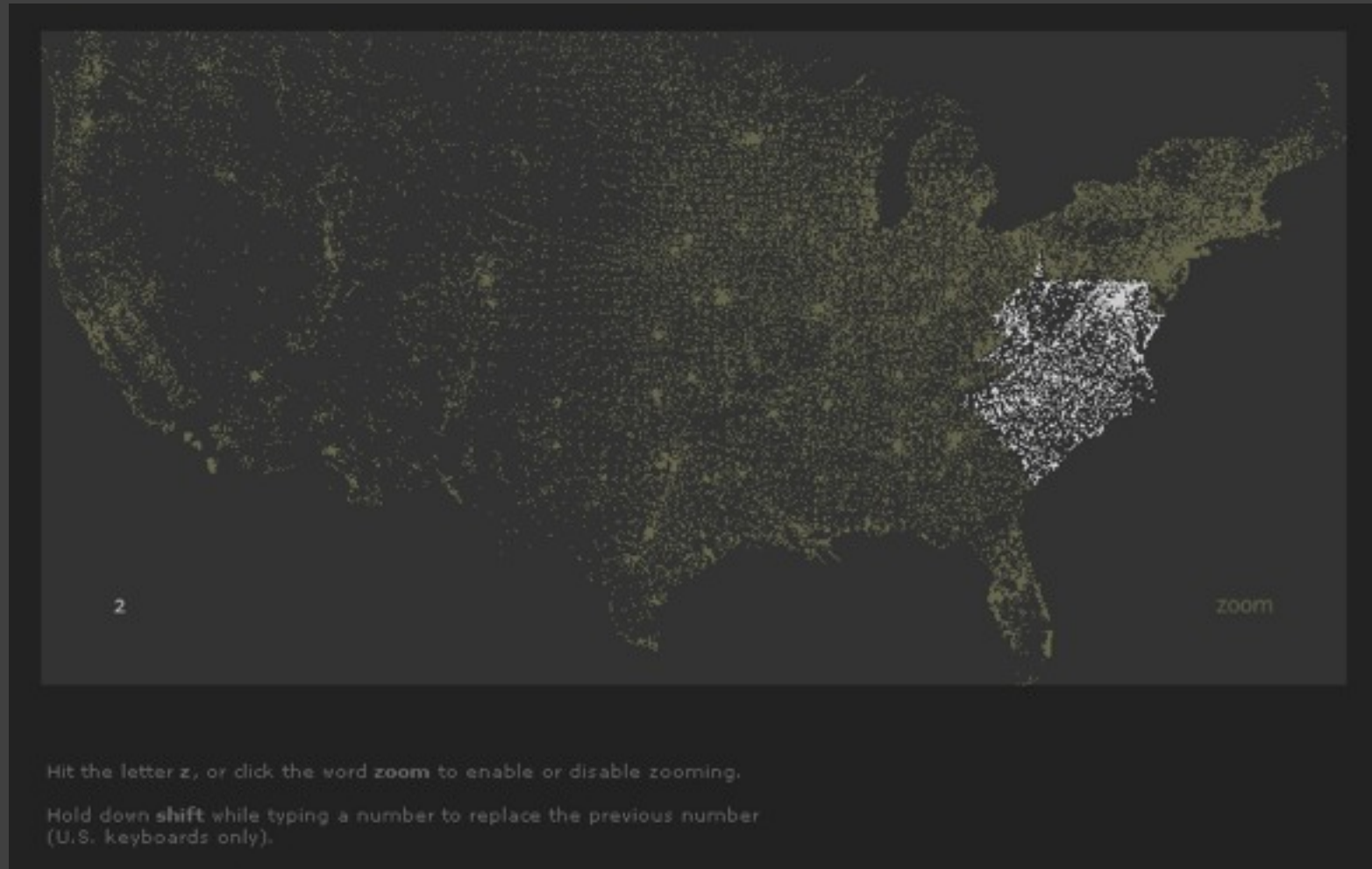
[Ahlberg and Shneiderman 94]

Attribute Explorer [Spence and Tweedie 98]

- Video Clip

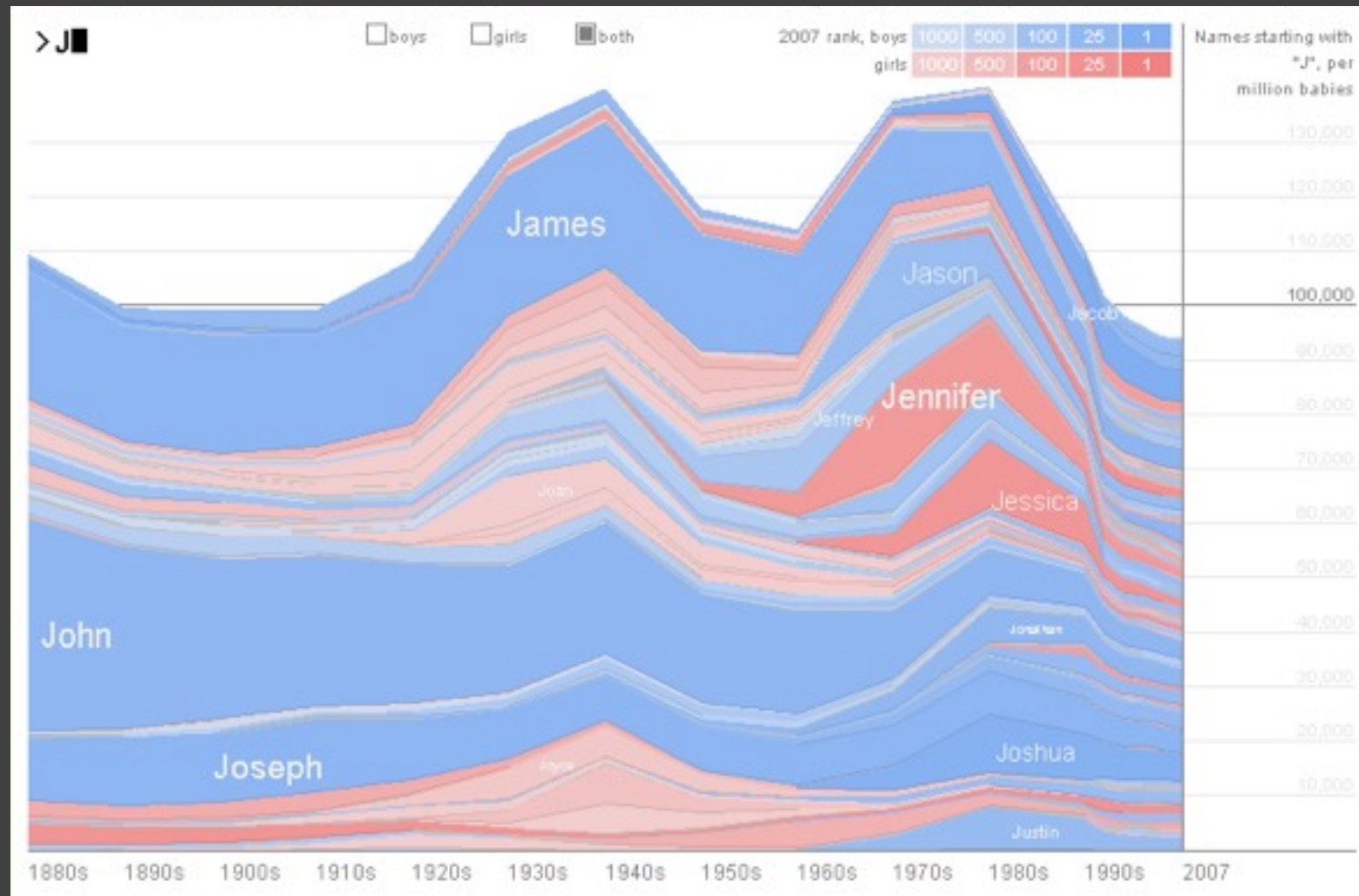
- The Attribute Explorer

Zipdecode [Fry 04]



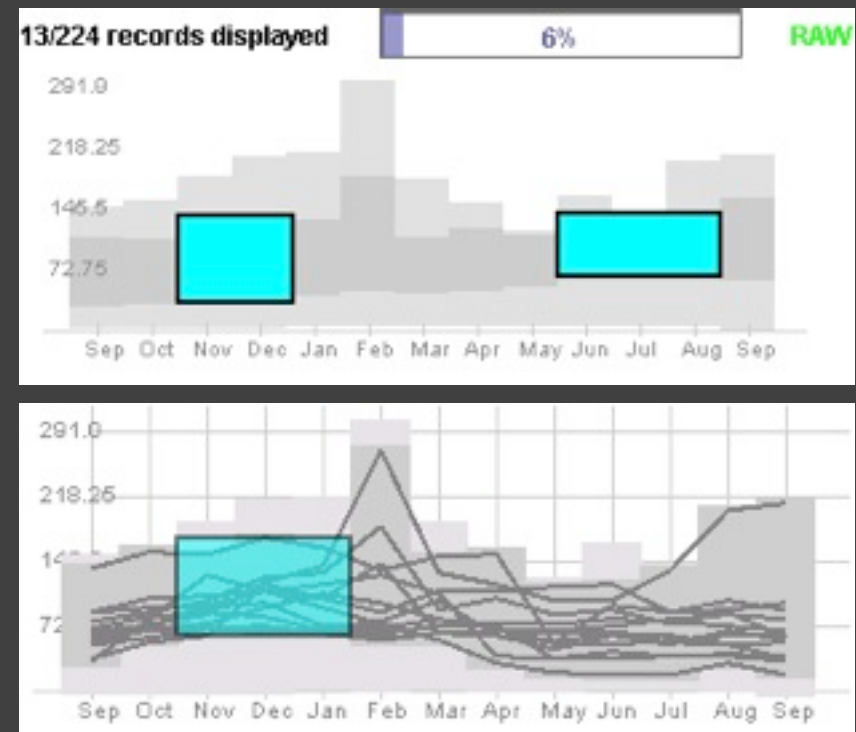
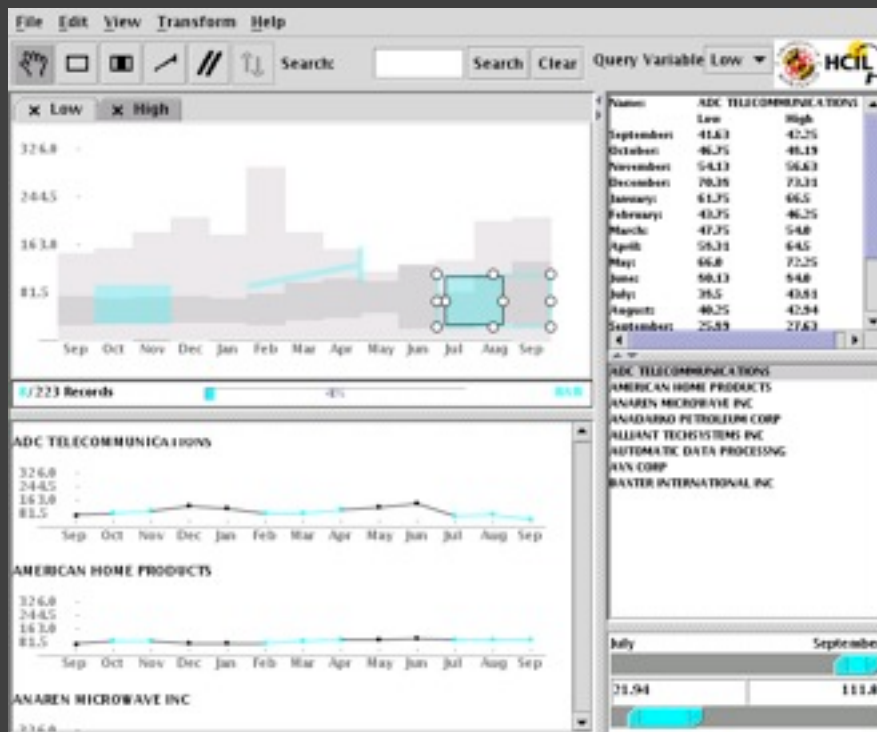
<http://benfry.com/zipdecode/>

Name Voyager



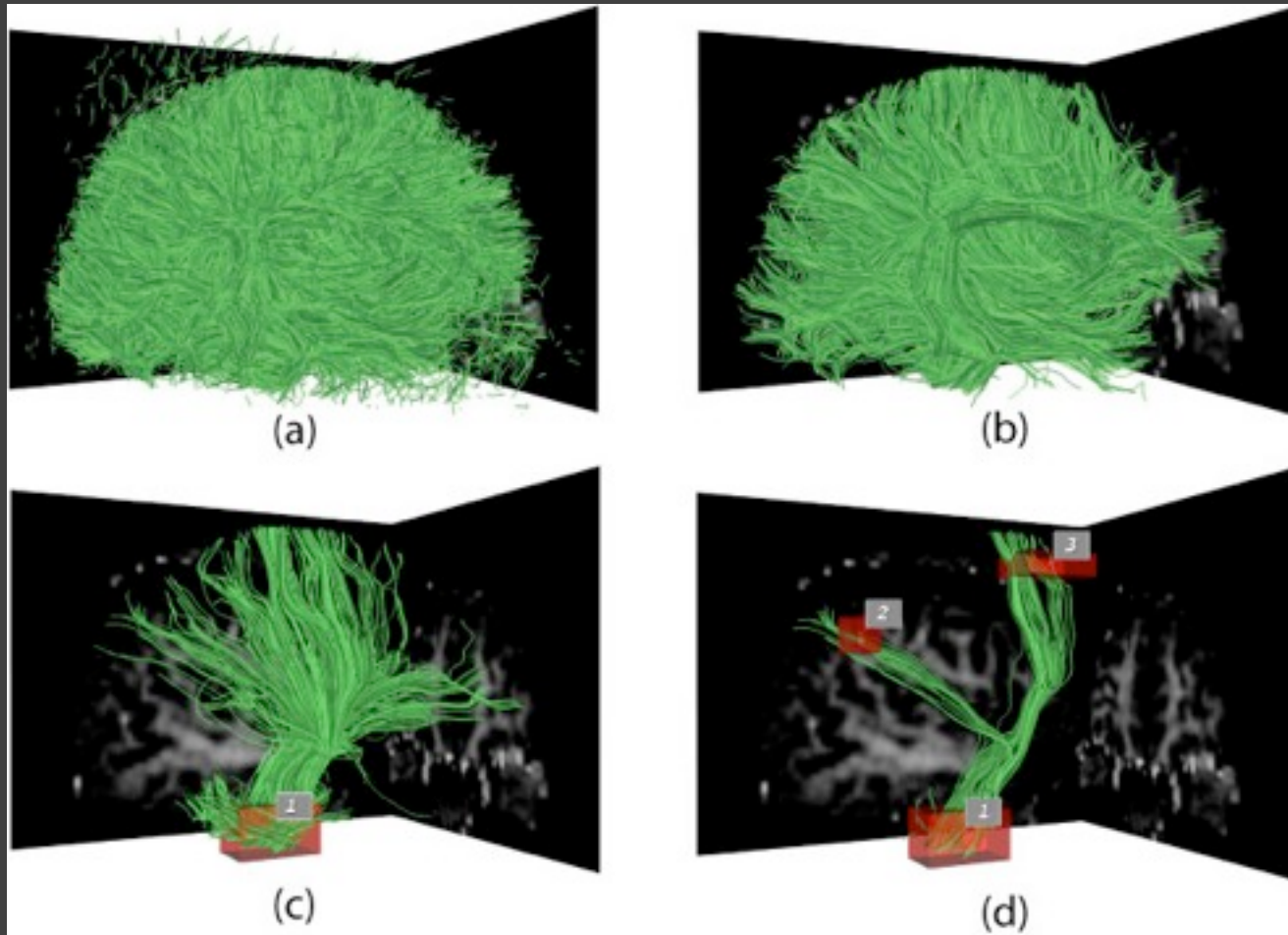
<http://www.babynamewizard.com/voyager>

TimeSearcher [Hochheiser & Shneiderman 02]

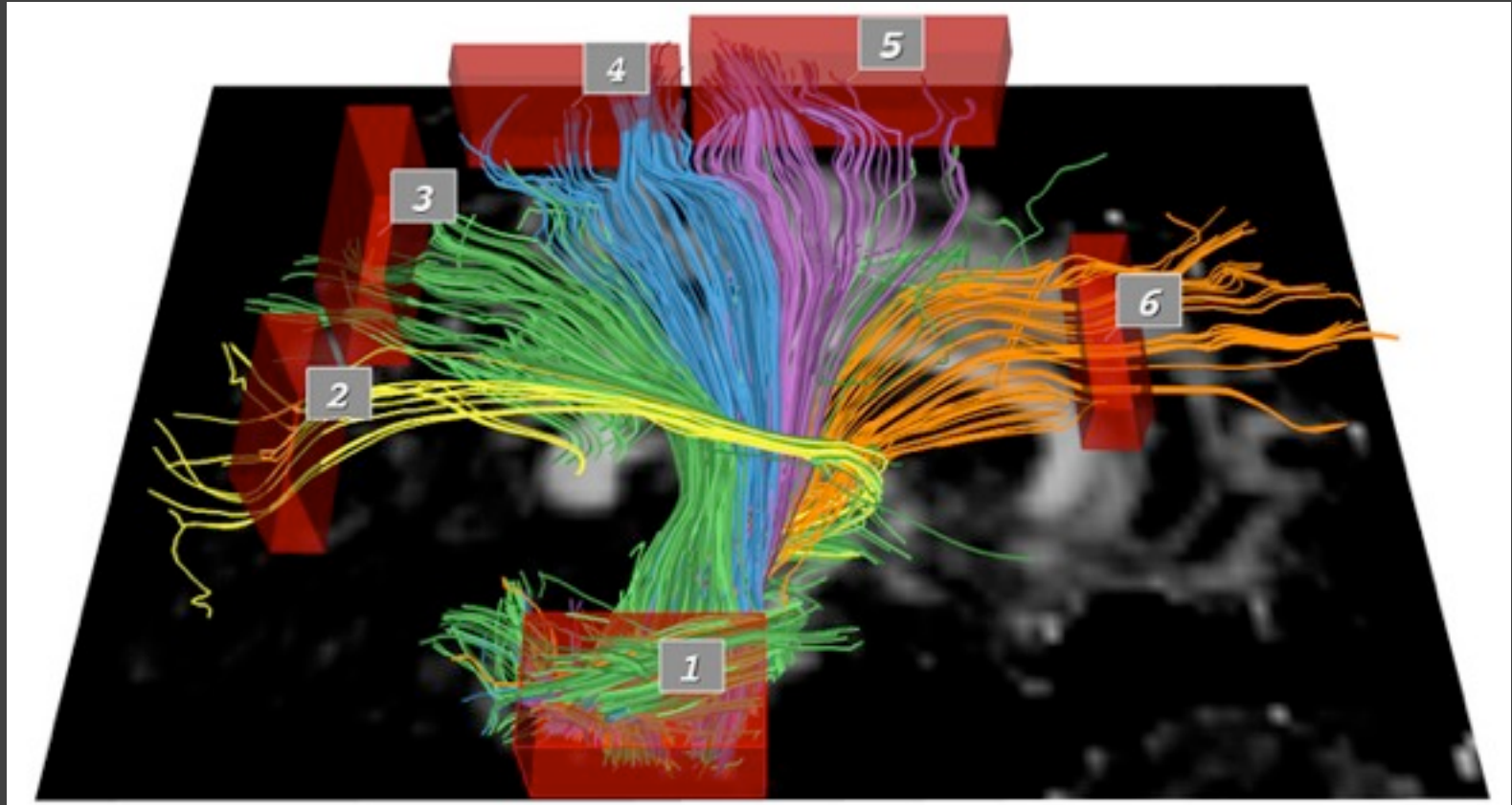


Based on Wattenberg's [2001] idea for sketch-based queries of time-series data.

3D dynamic queries [Akers et al. 04]



3D dynamic queries [Akers et al. 04]



Pros and Cons

Pros

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

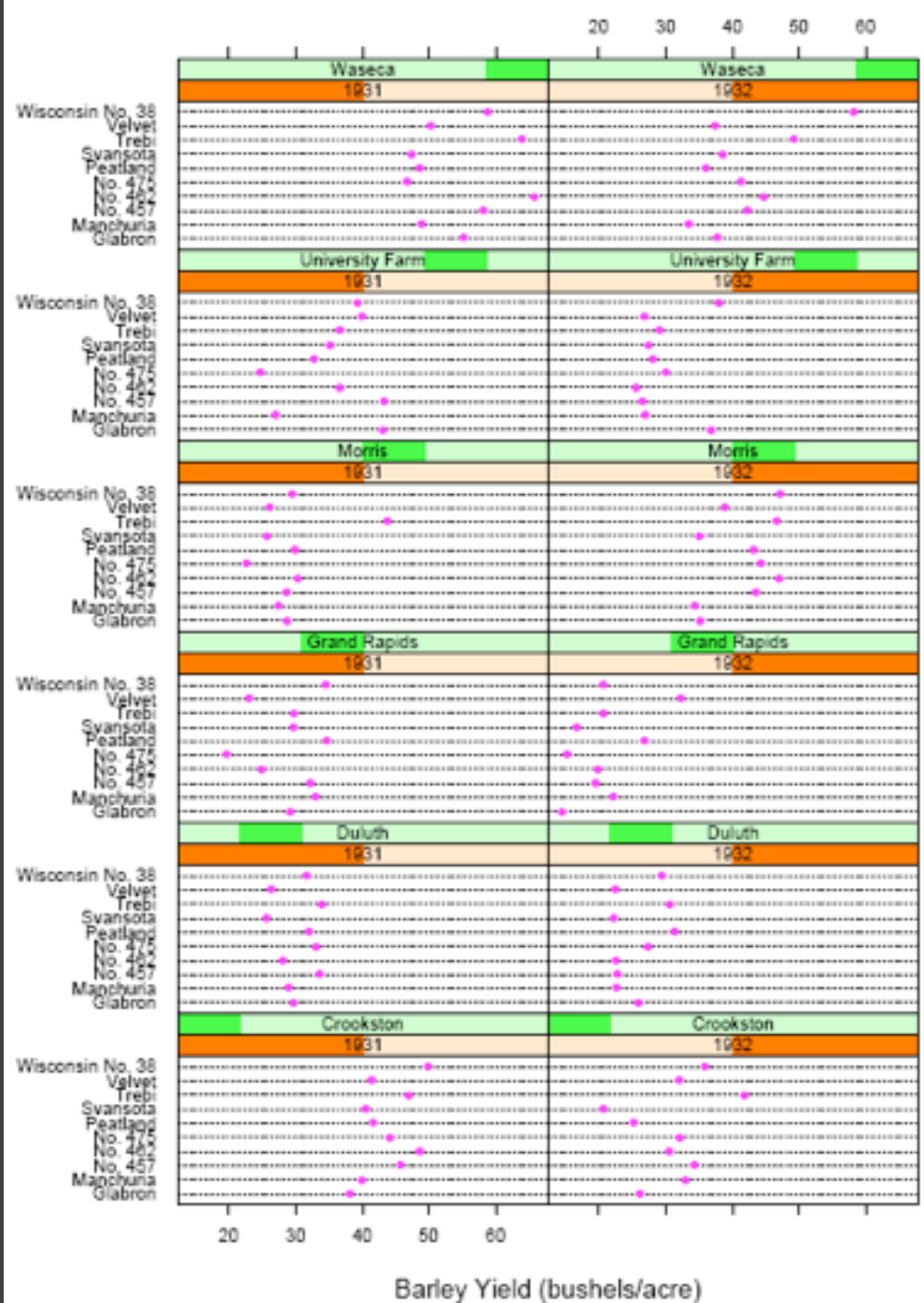
Cons

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

Sorting

Trellis Display

[Becker, Cleveland, and Shyu 96]

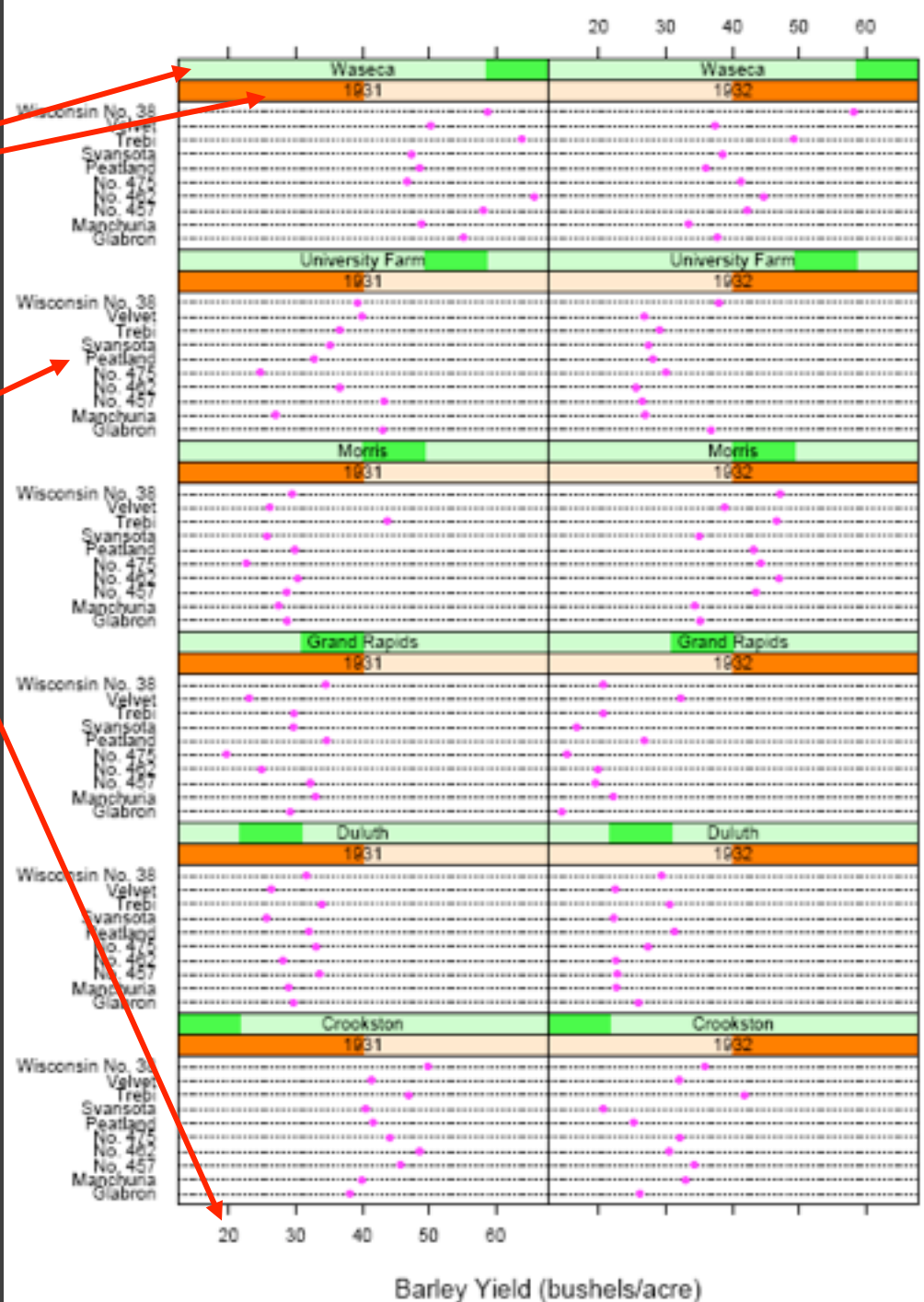


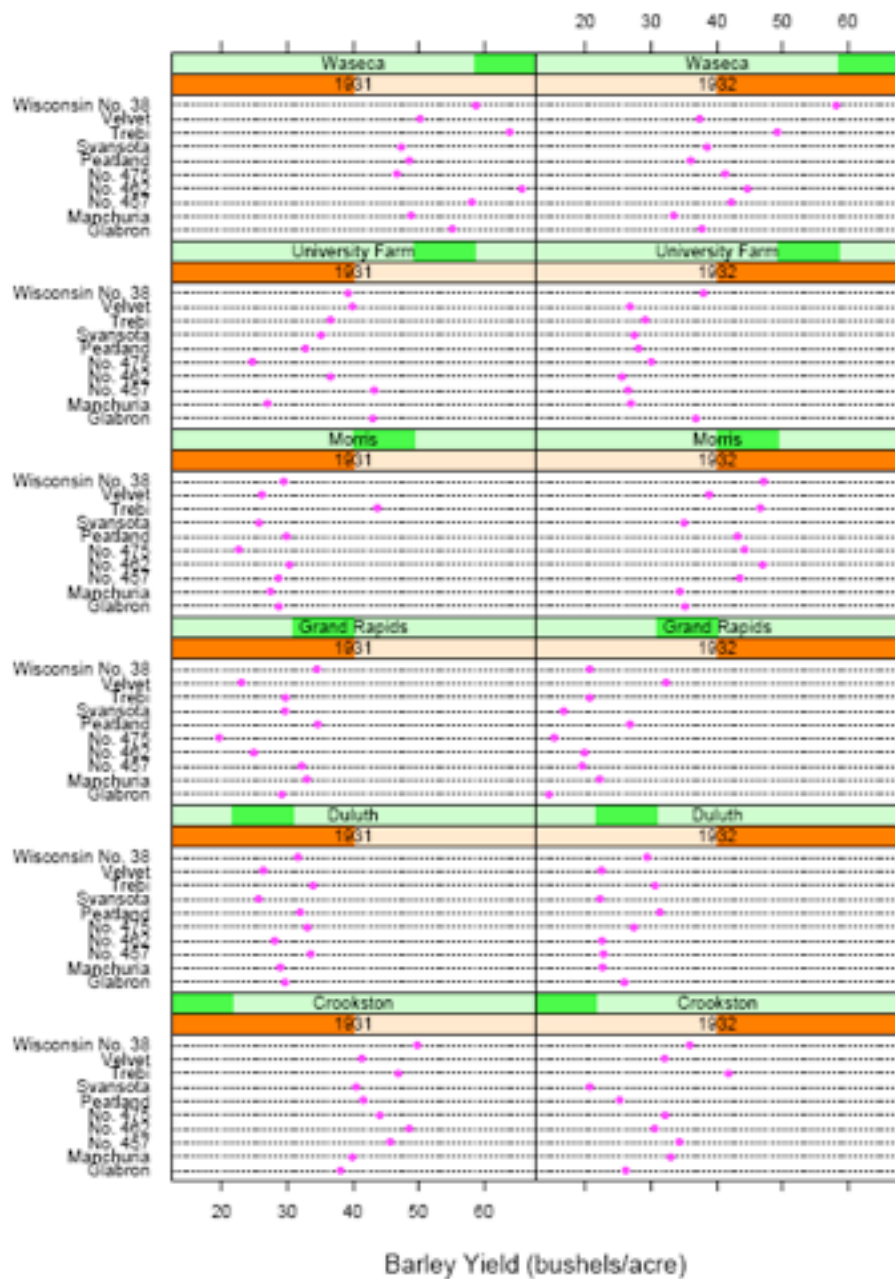
Condition variables
location, year

Panel variables
type, yield

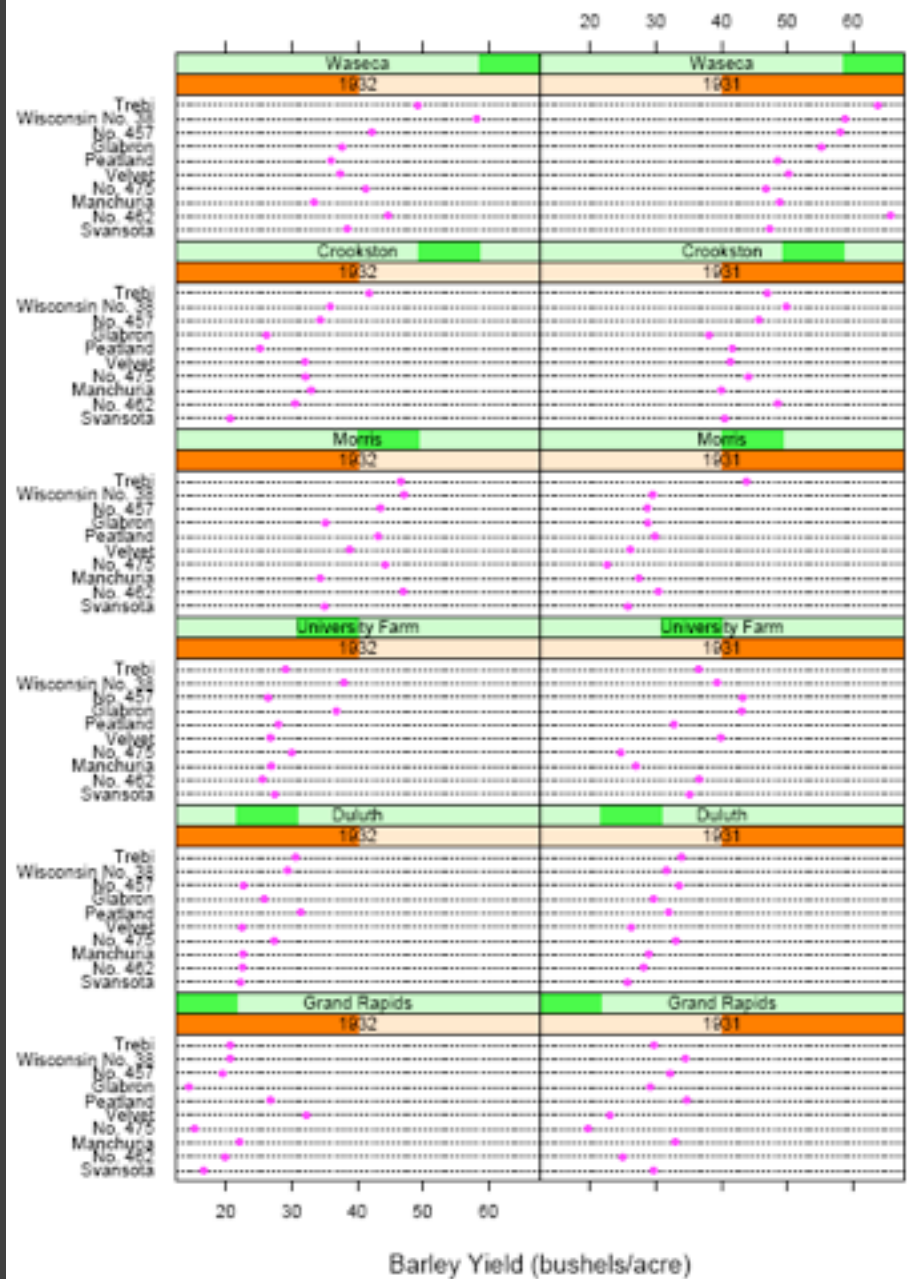
Trellis Display

[Becker, Cleveland, and Shyu 96]

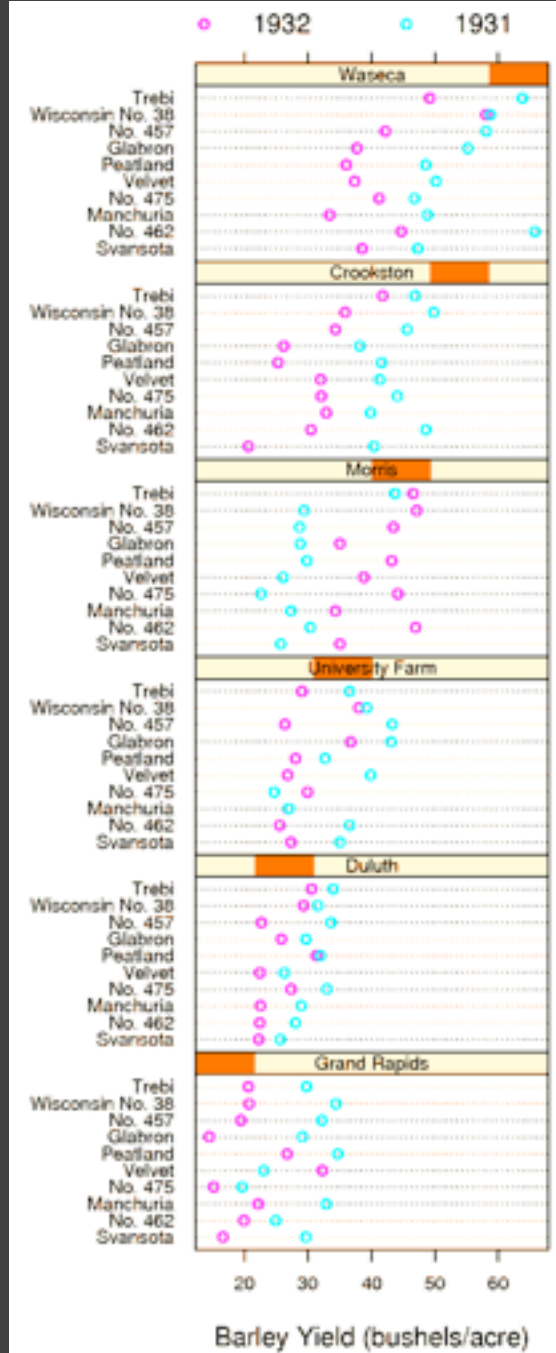




Alphabetical ordering



Main-effects ordering



Graph Viewer

Roll-up by:

All

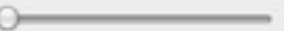
Visualization:

Node-Link

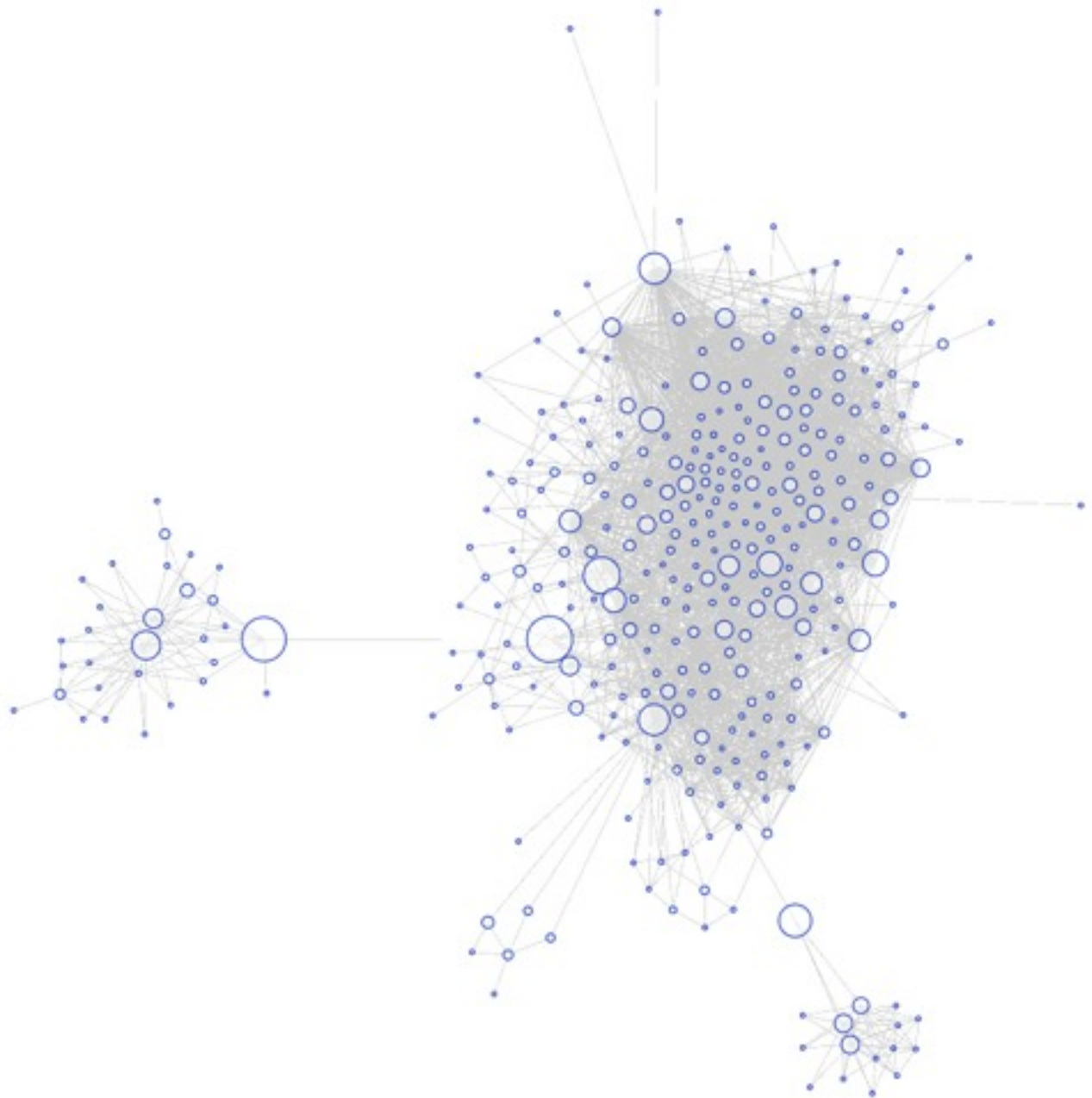
Sort by:

None

Edge centrality filters:



- ☐ Images
- ☒ Animate



Graph Viewer

Roll-up by:

All

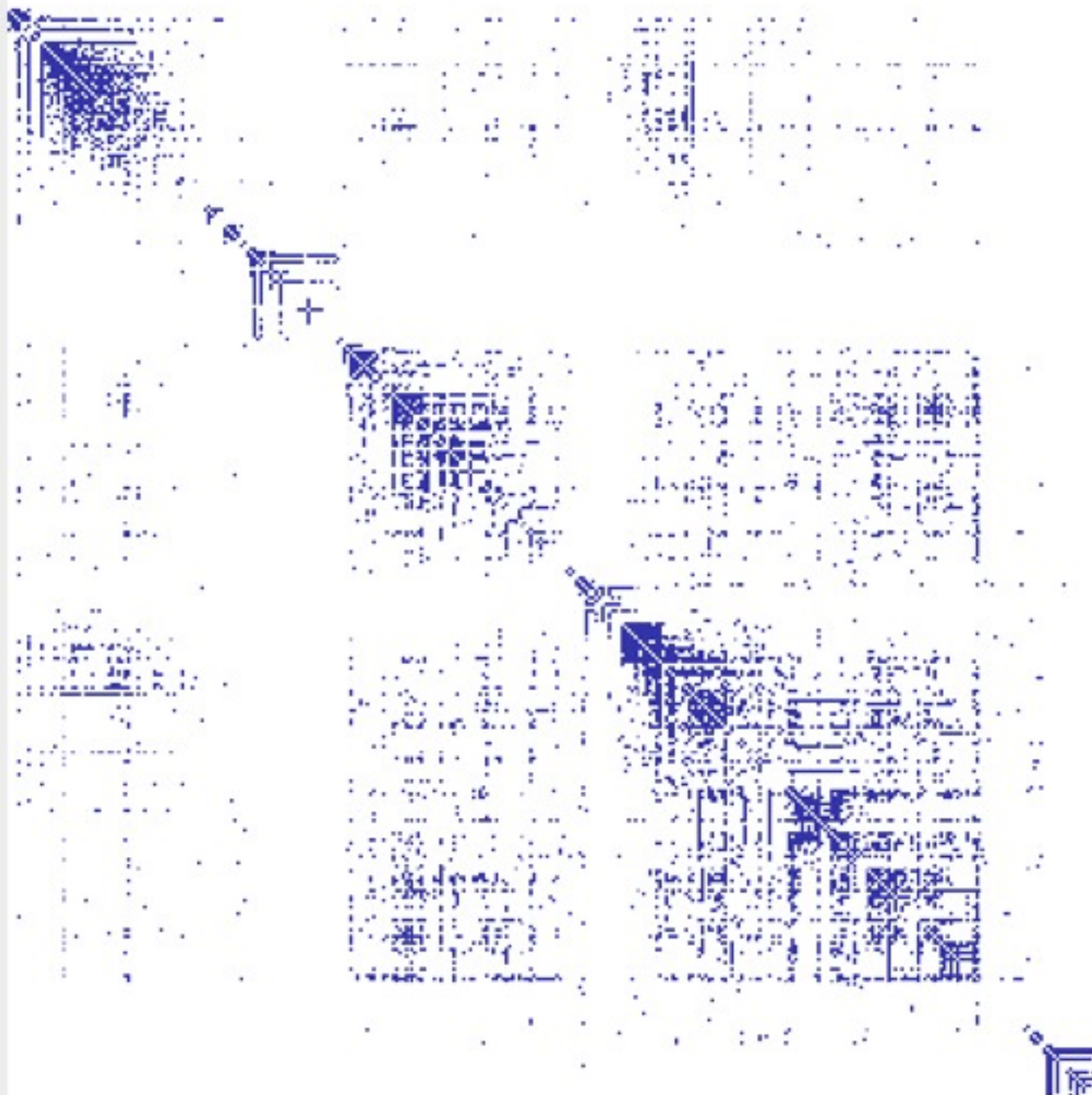
Visualization:

Matrix

Sort by:

Linkage

Edge centrality filters:

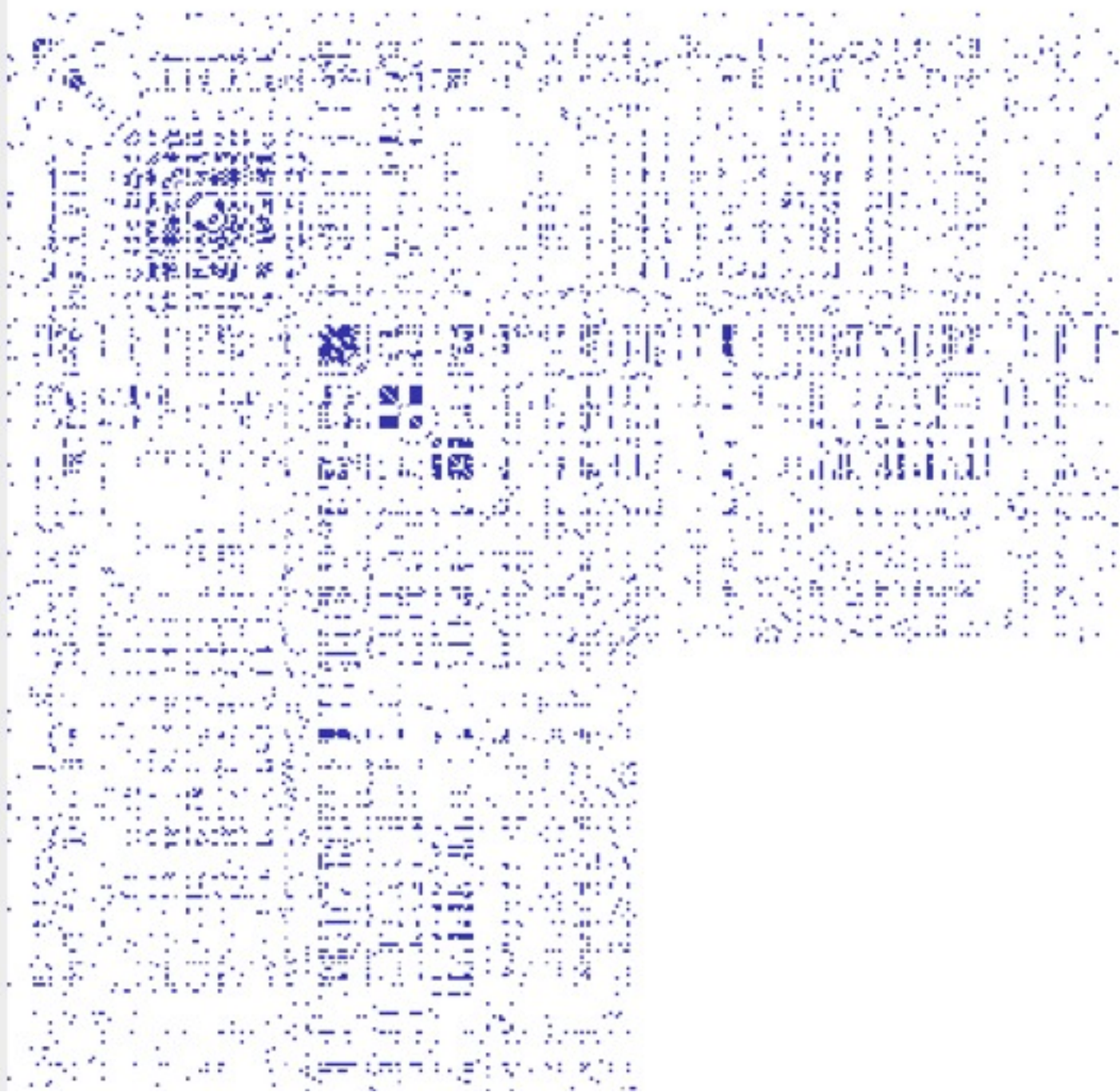


Roll-up by:

All

Matrix

None



Administrivia

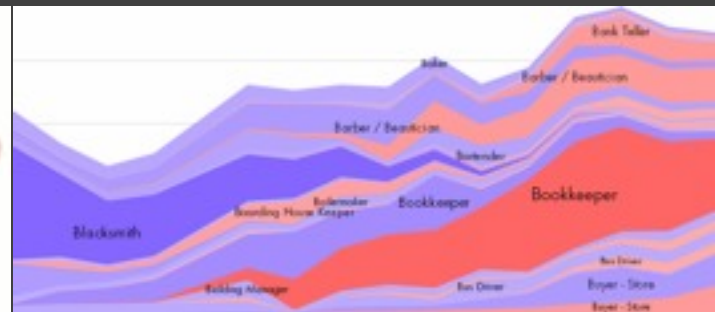
A3: Interactive Visualization

Create an interactive visualization application. Choose a data domain and select an appropriate visualization technique.

1. Choose a data set and storyboard your interface
2. Implement the interface using tools of your choice
3. Submit your application and produce a final write-up

You should work in groups of 2.

Due by 5pm on **Monday, February 10**

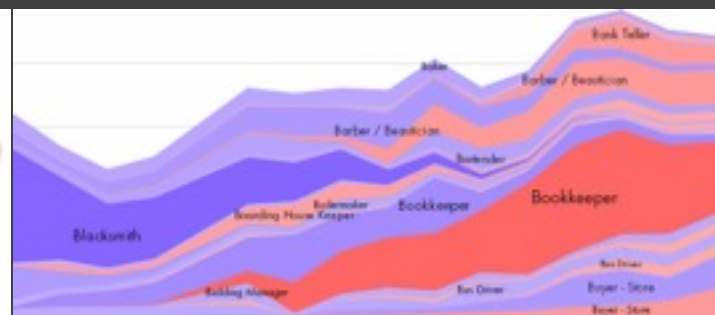


Assignment 3: Project Partners

For A3, you should work in **groups of 2**.

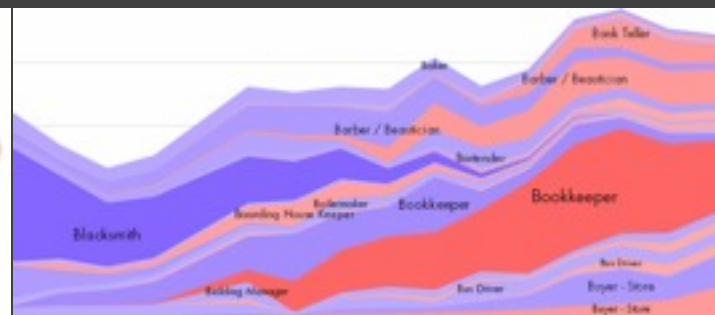
If you do not have a partner, you should

- 1) Use the facilities on Piazza
- 2) Stay after class to meet potential partners



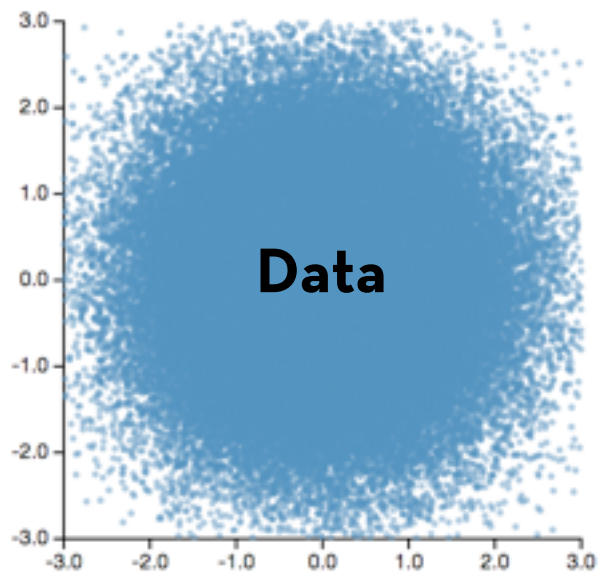
Assignment 3 Tips

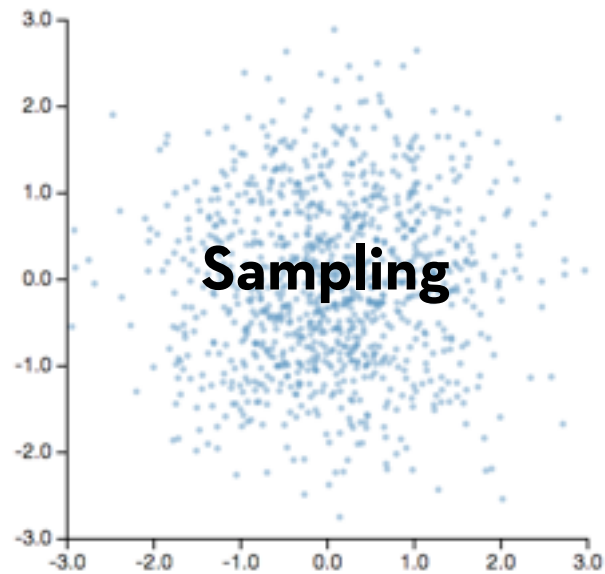
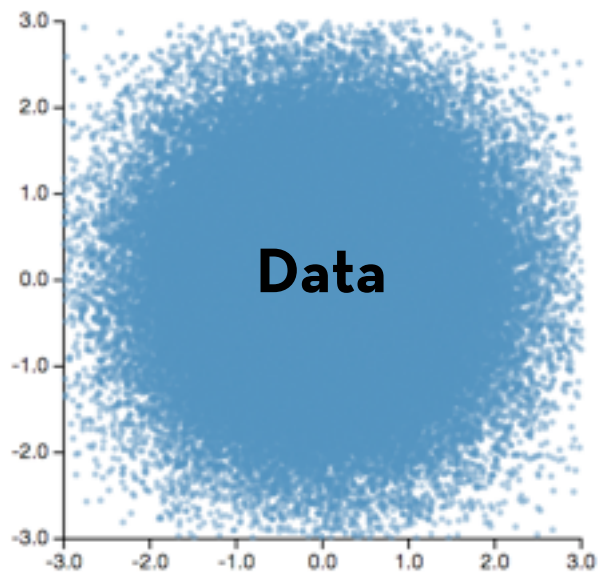
- 1) Start now.** It will take longer than you think.
- 2) Keep it simple.** (Eschew the kitchen sink.)
Choose the minimal set of interactions that enables users to explore and generate interesting insights. Keep the design clean.
- 3) Promote engagement.** How do your chosen interactions reveal interesting observations?

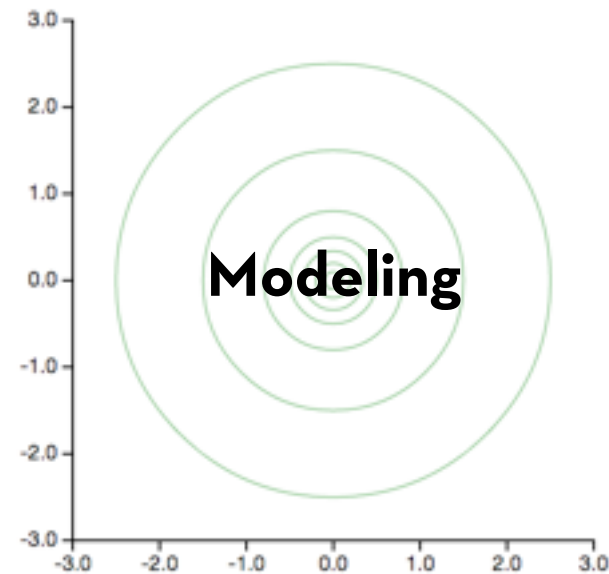
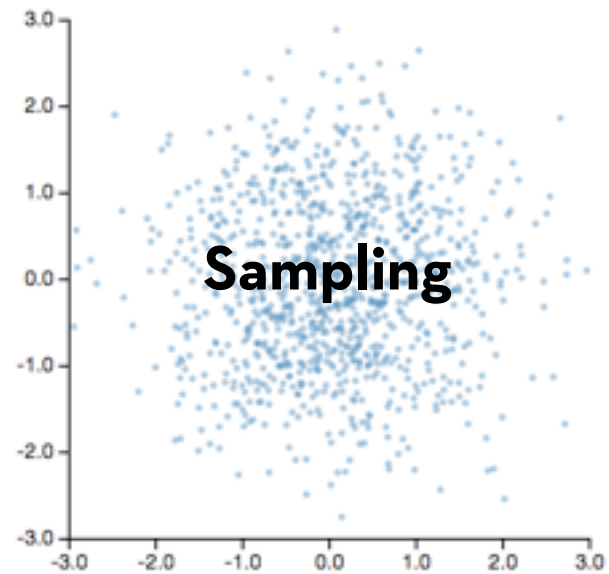
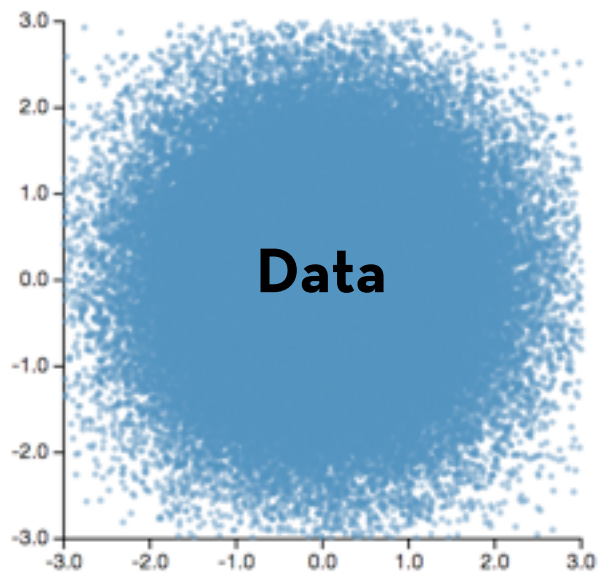


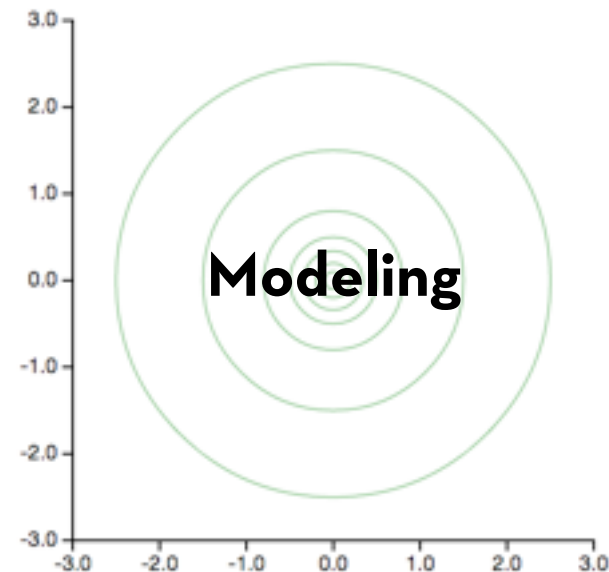
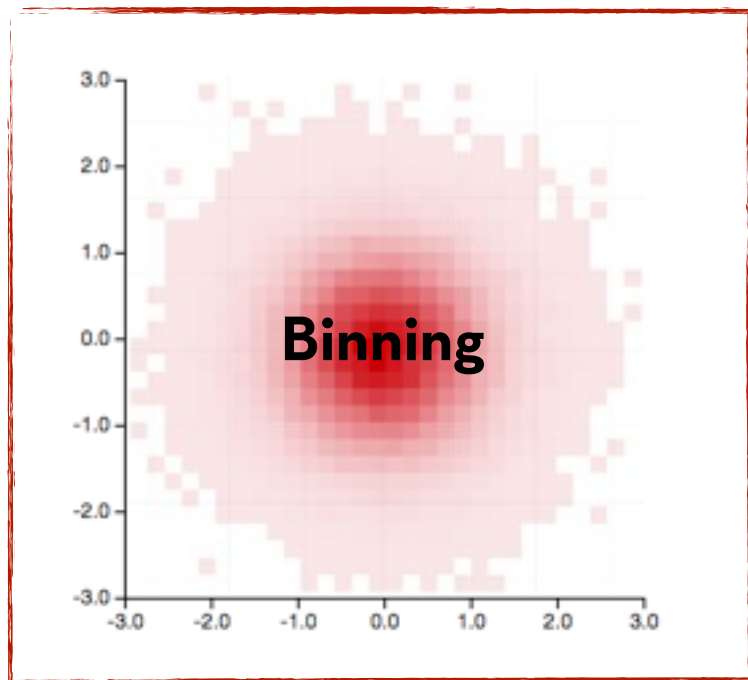
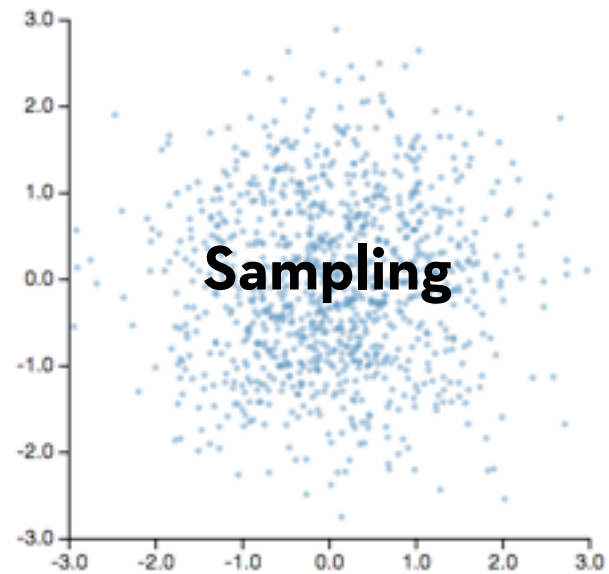
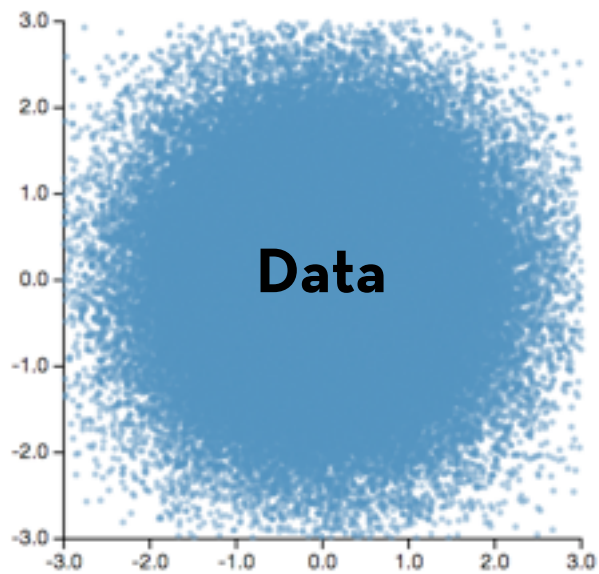
imMens

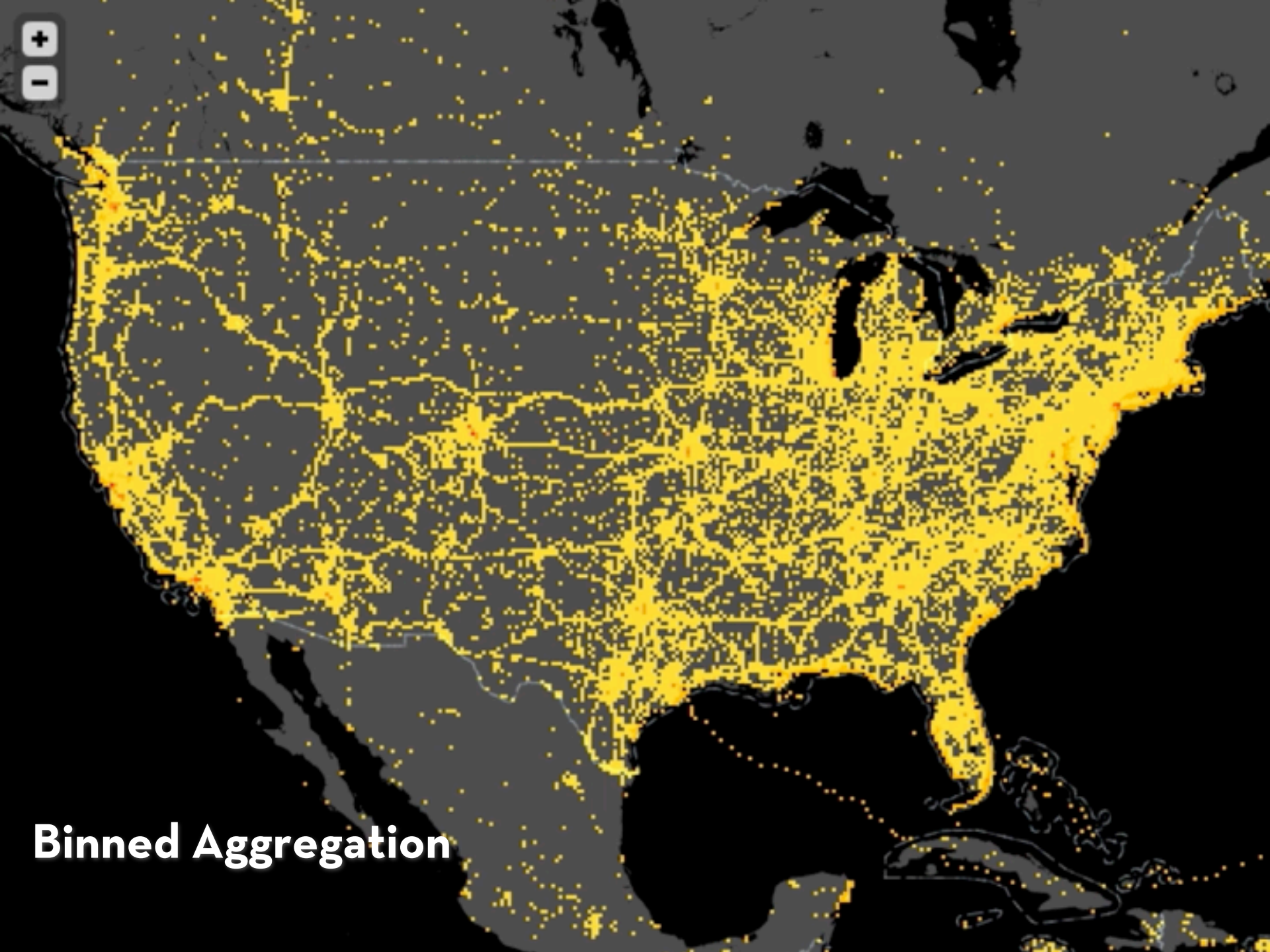
How can we visualize and
interact with **billion+ record**
databases in real-time?



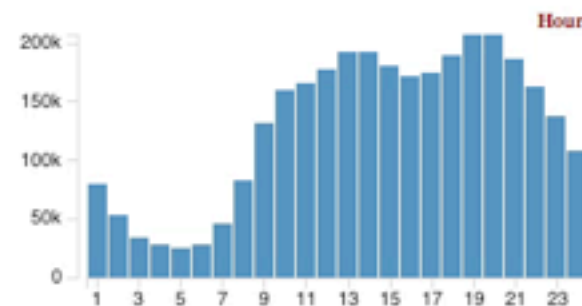
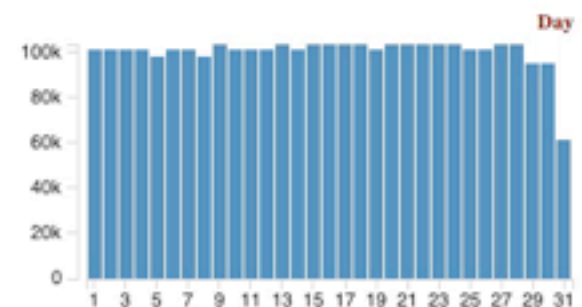
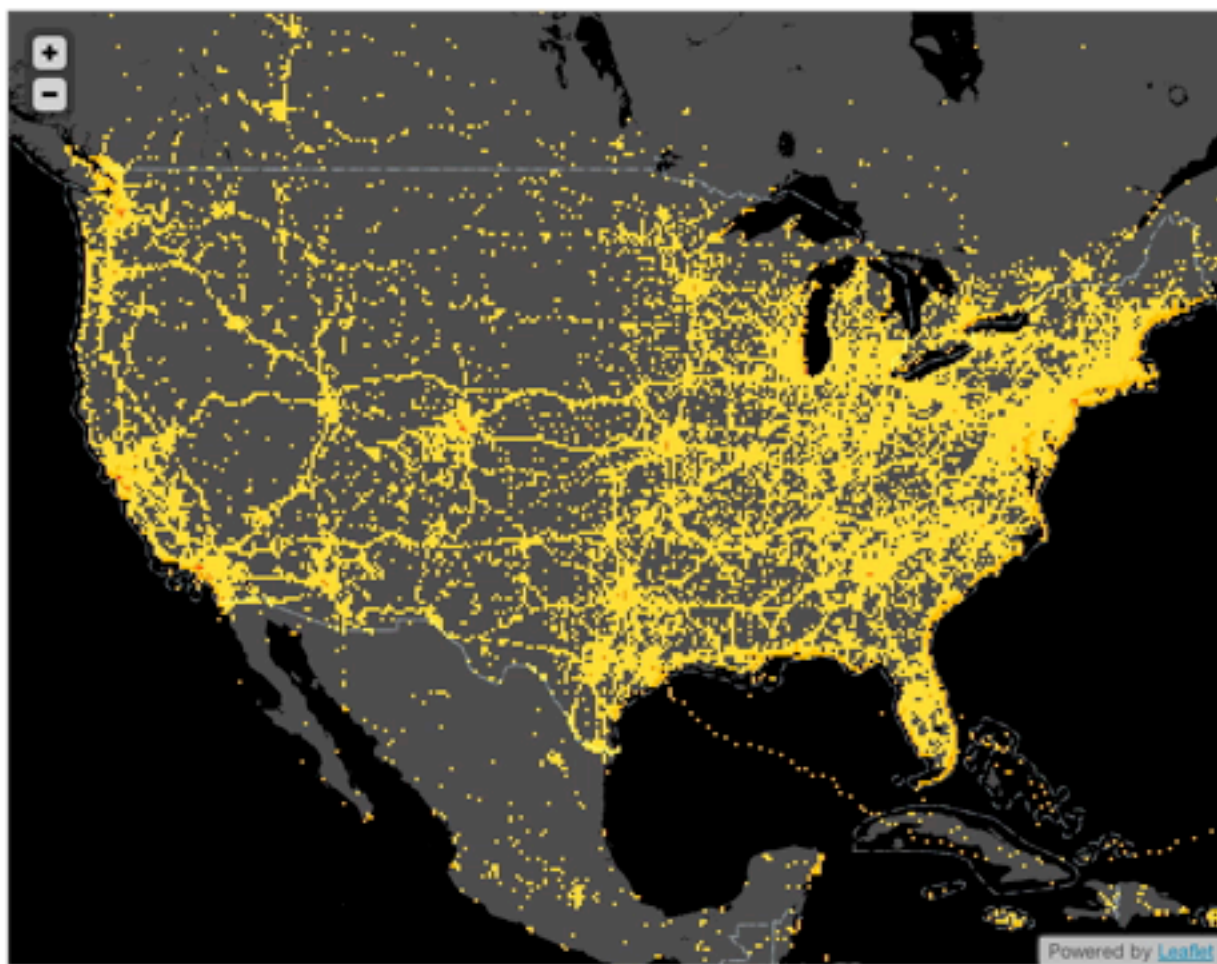








Binned Aggregation



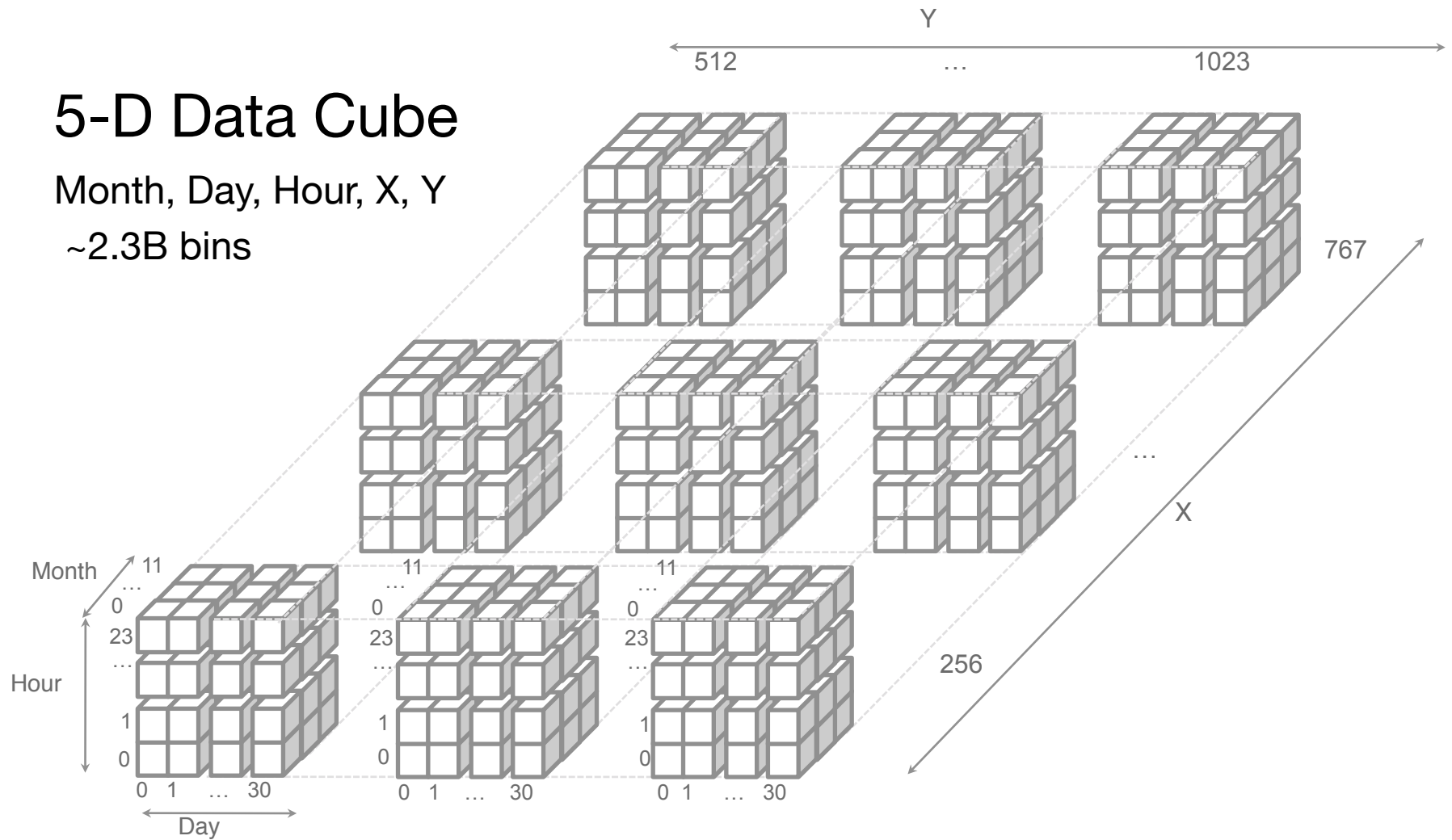
***imMens*: Real-Time Visual Querying of Big Data**

with Zhicheng (Leo) Liu & Biye Jiang

5-D Data Cube

Month, Day, Hour, X, Y

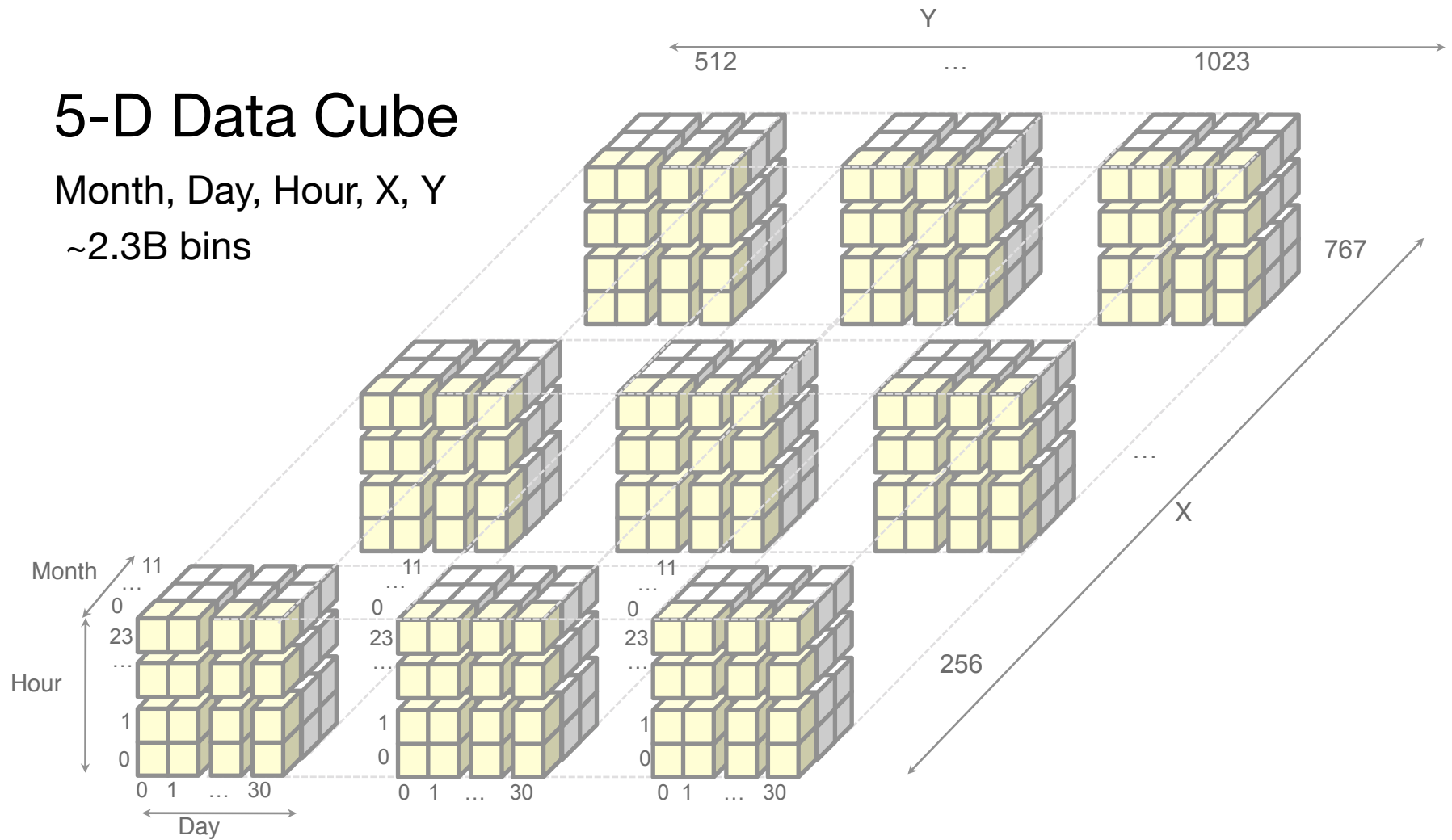
~2.3B bins

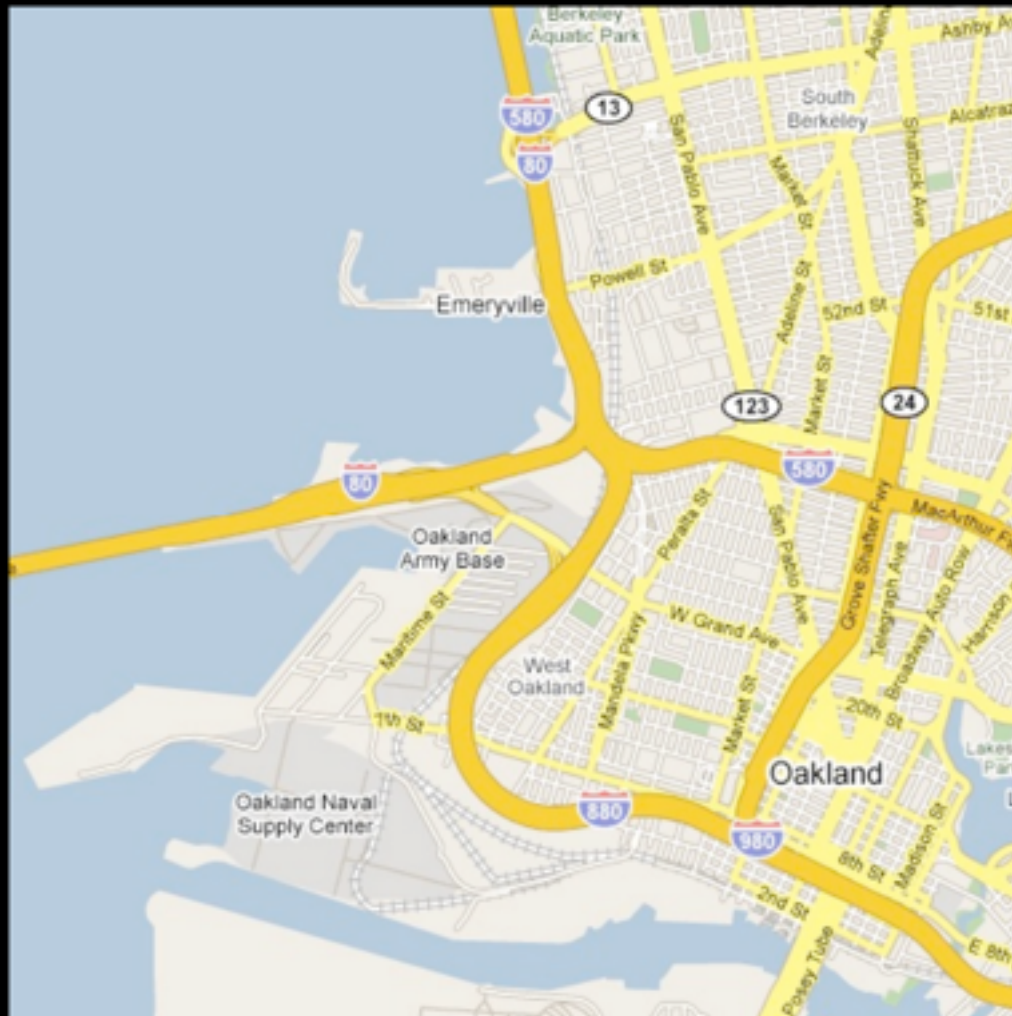


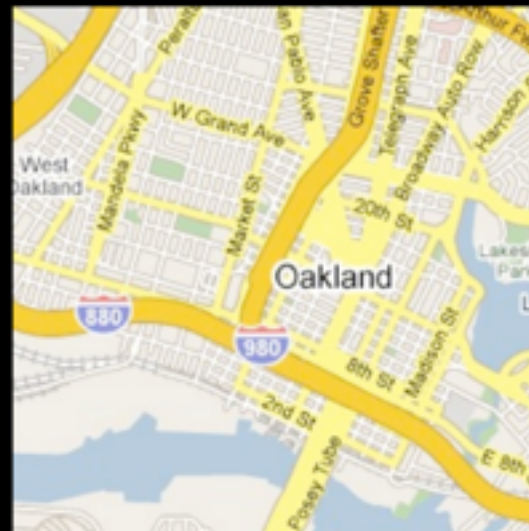
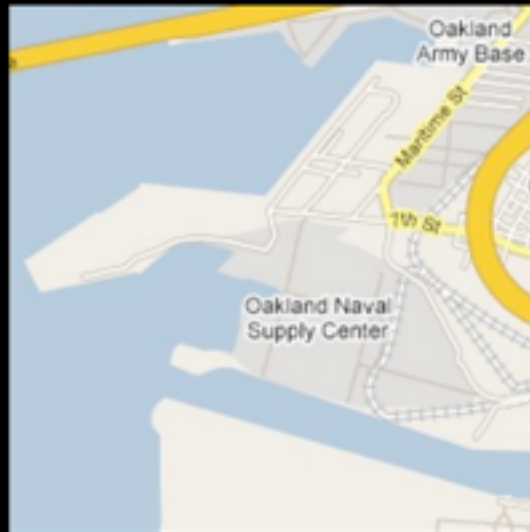
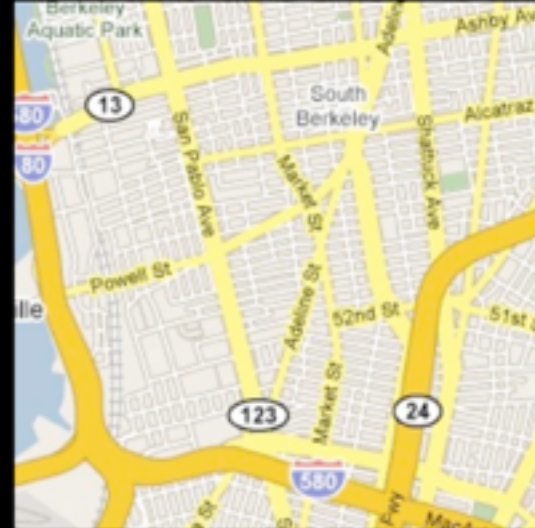
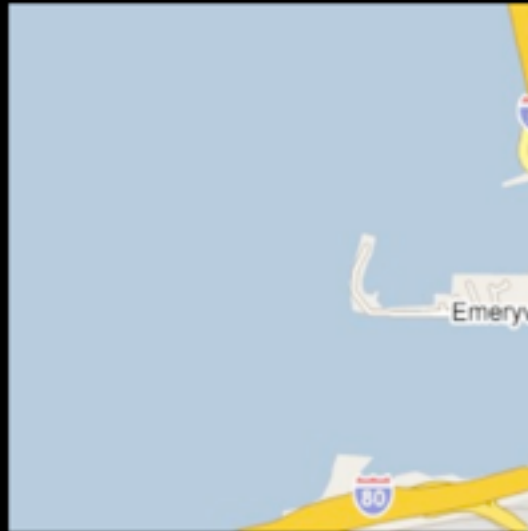
5-D Data Cube

Month, Day, Hour, X, Y

~2.3B bins

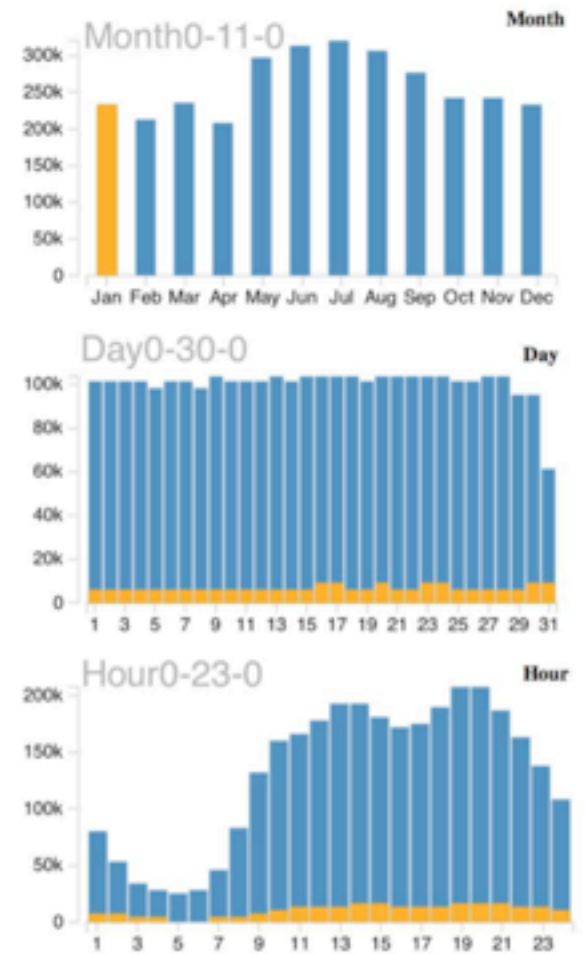
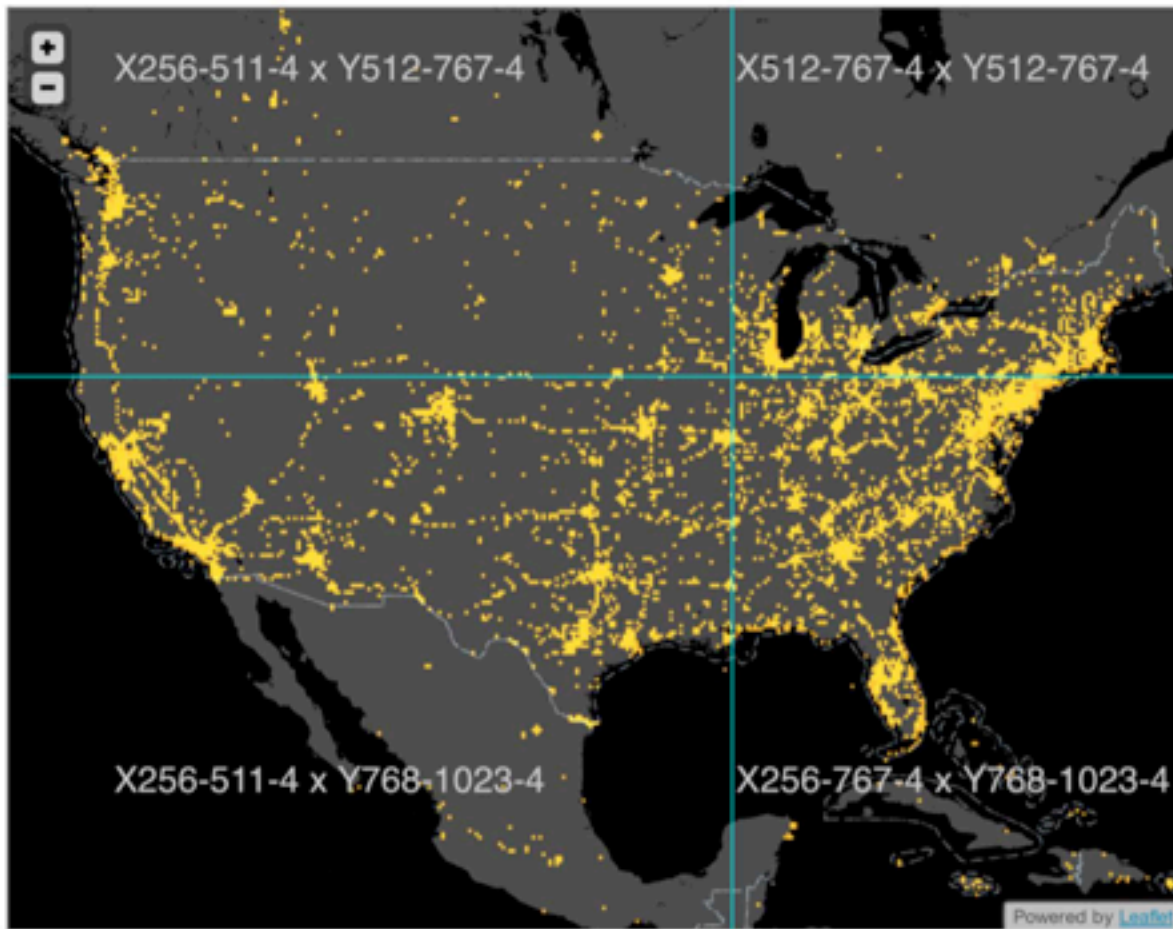


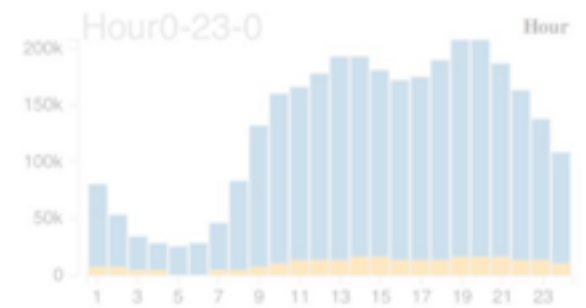
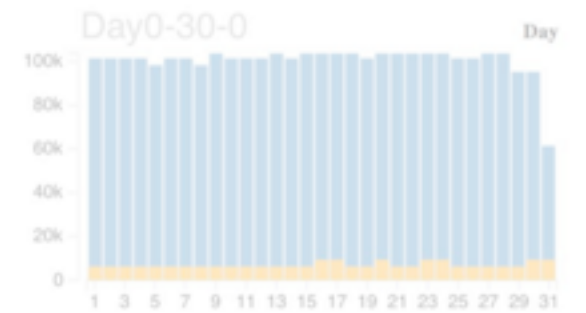
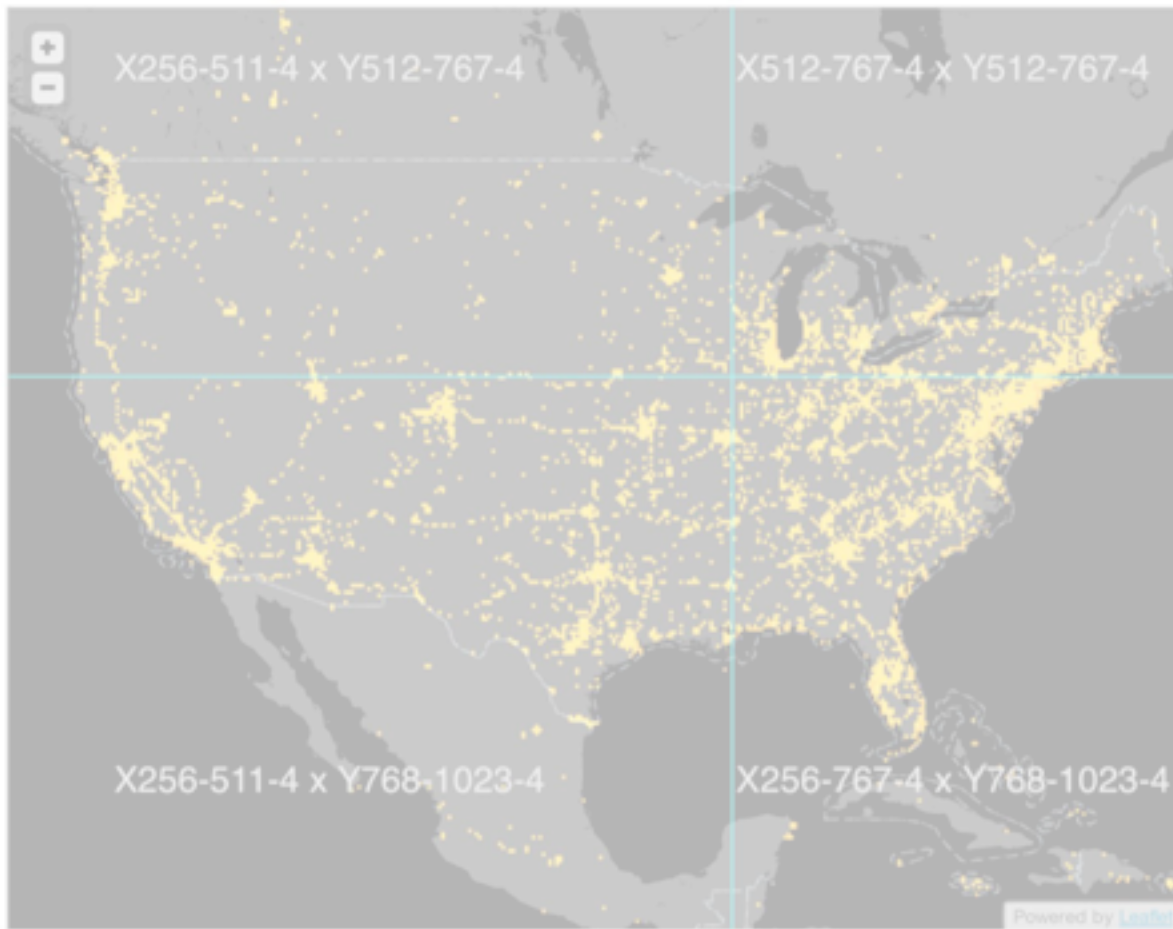


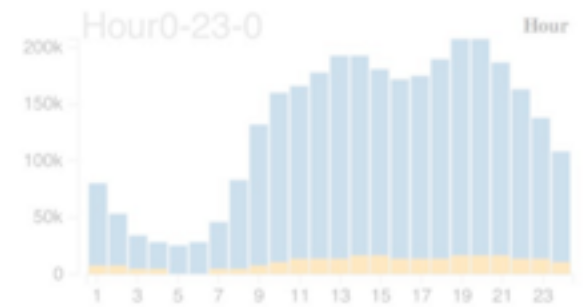
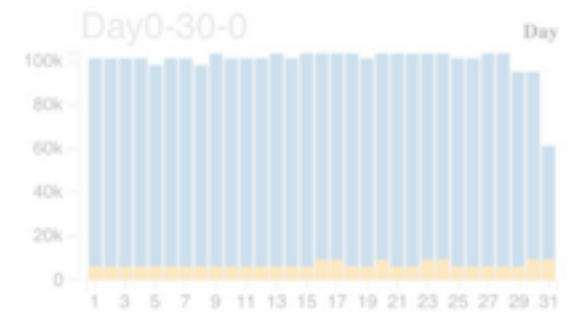
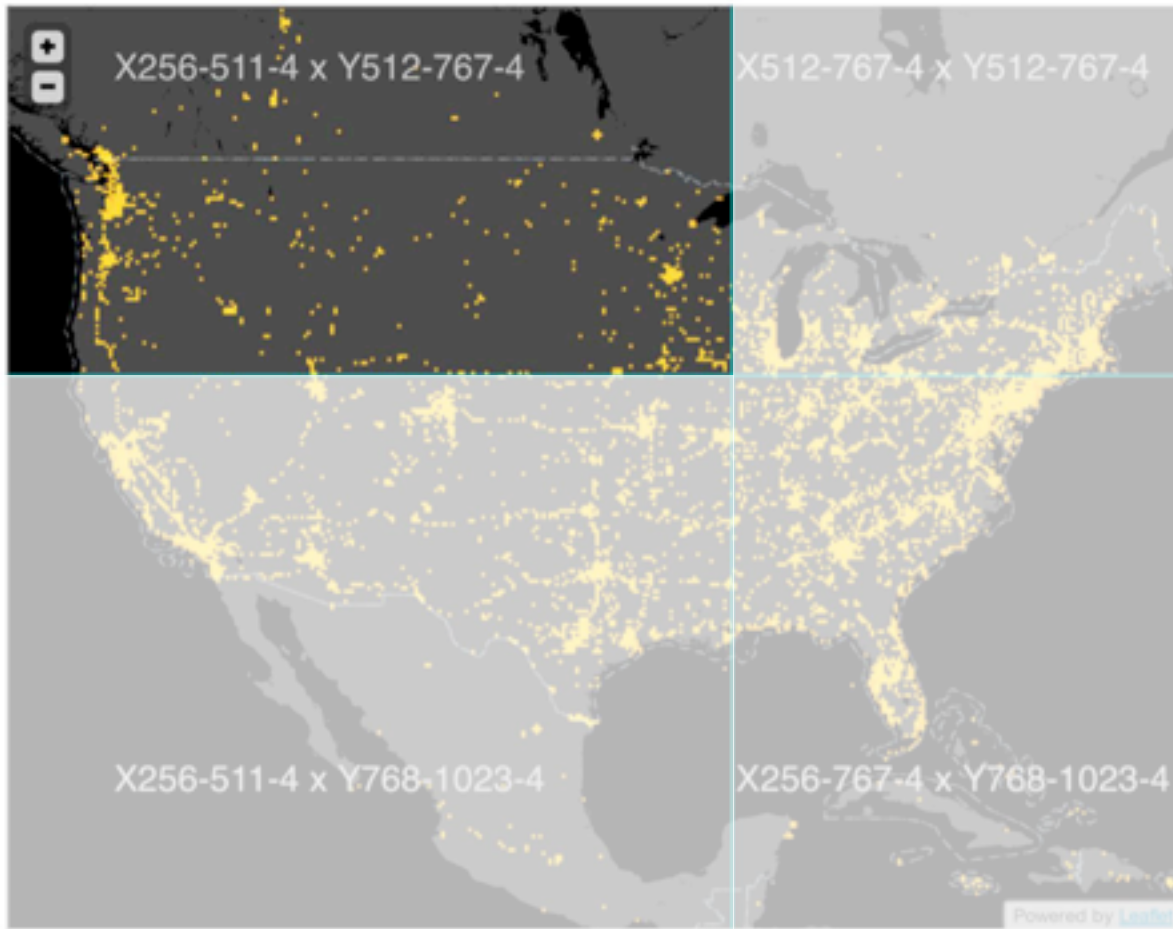


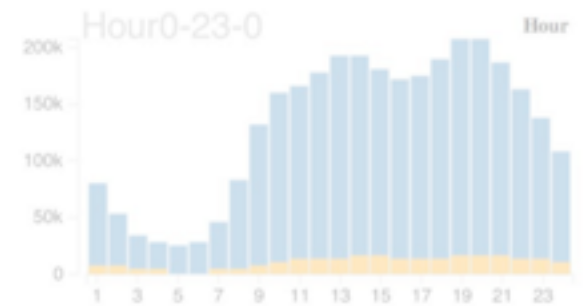
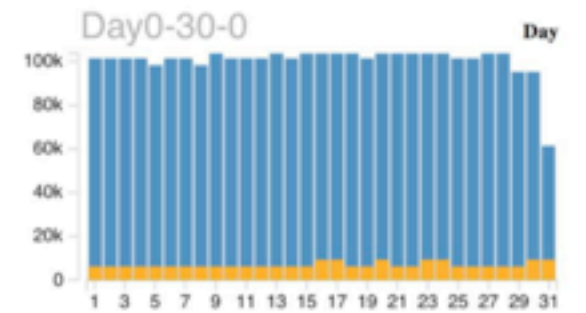
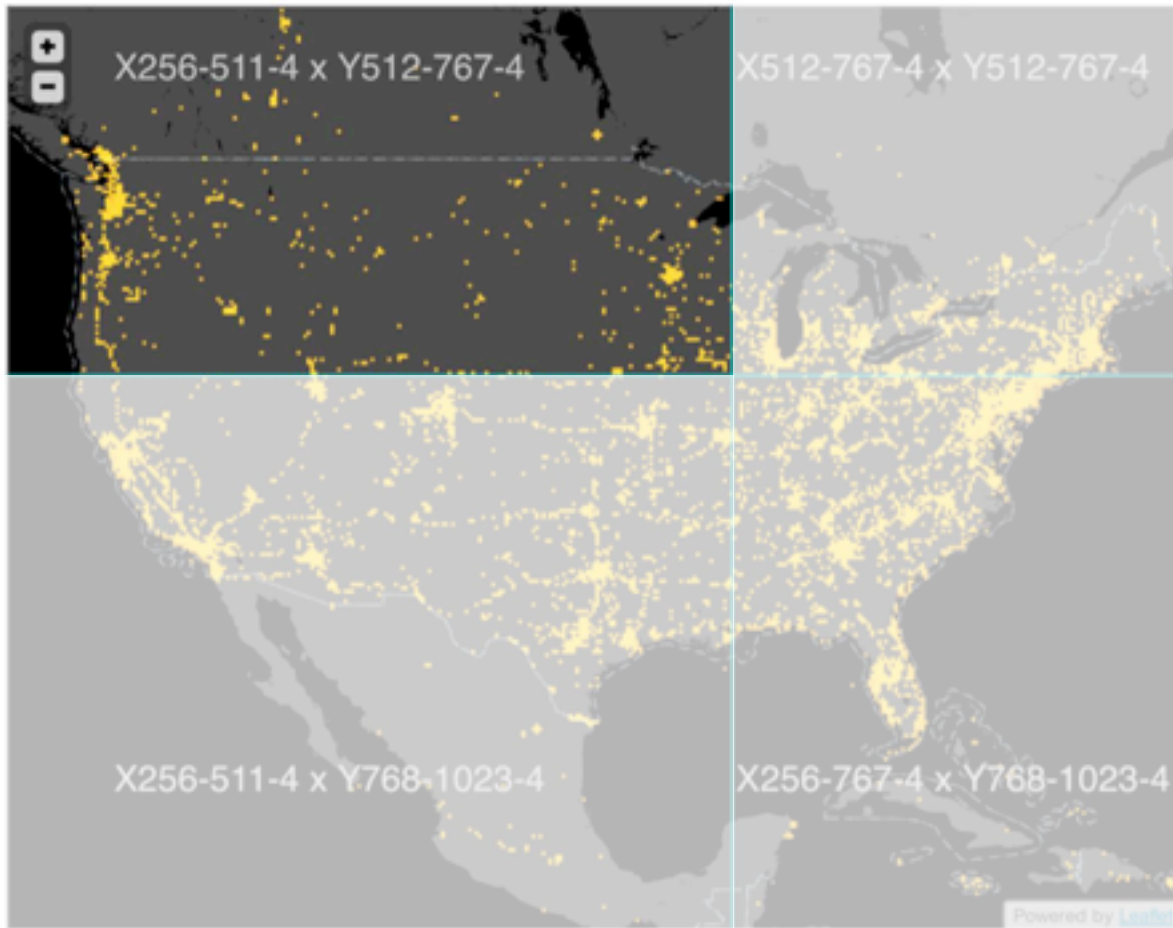
Multivariate Data Tiles

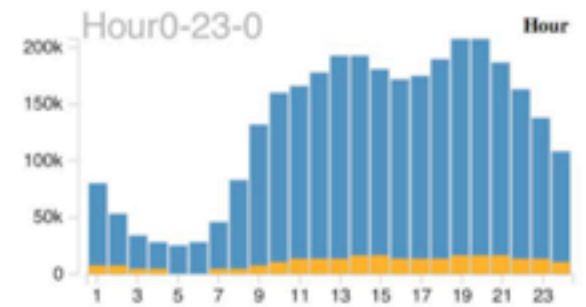
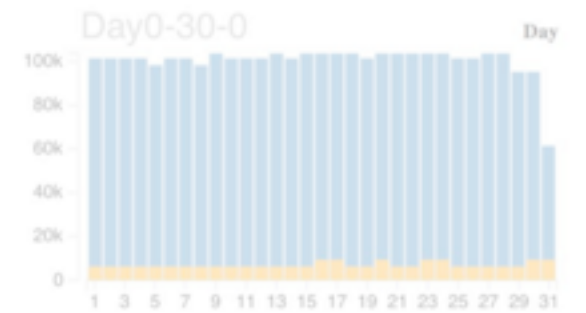
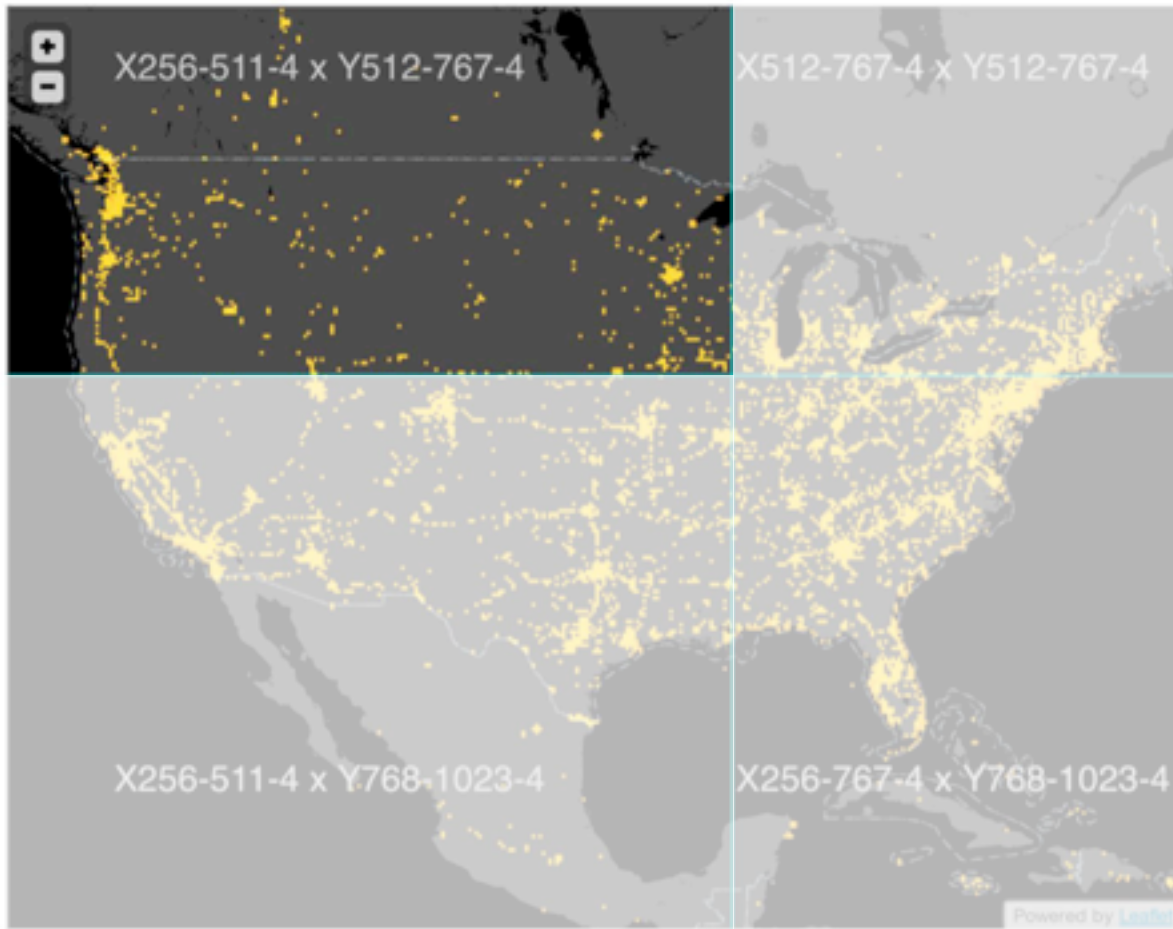
1. Send data, not pixels
2. Embed multi-dim data

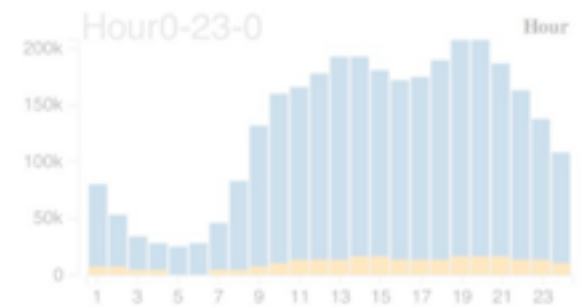
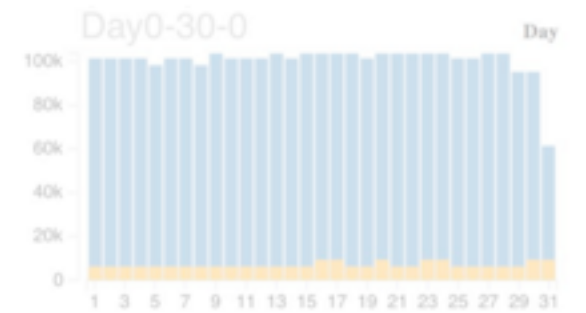
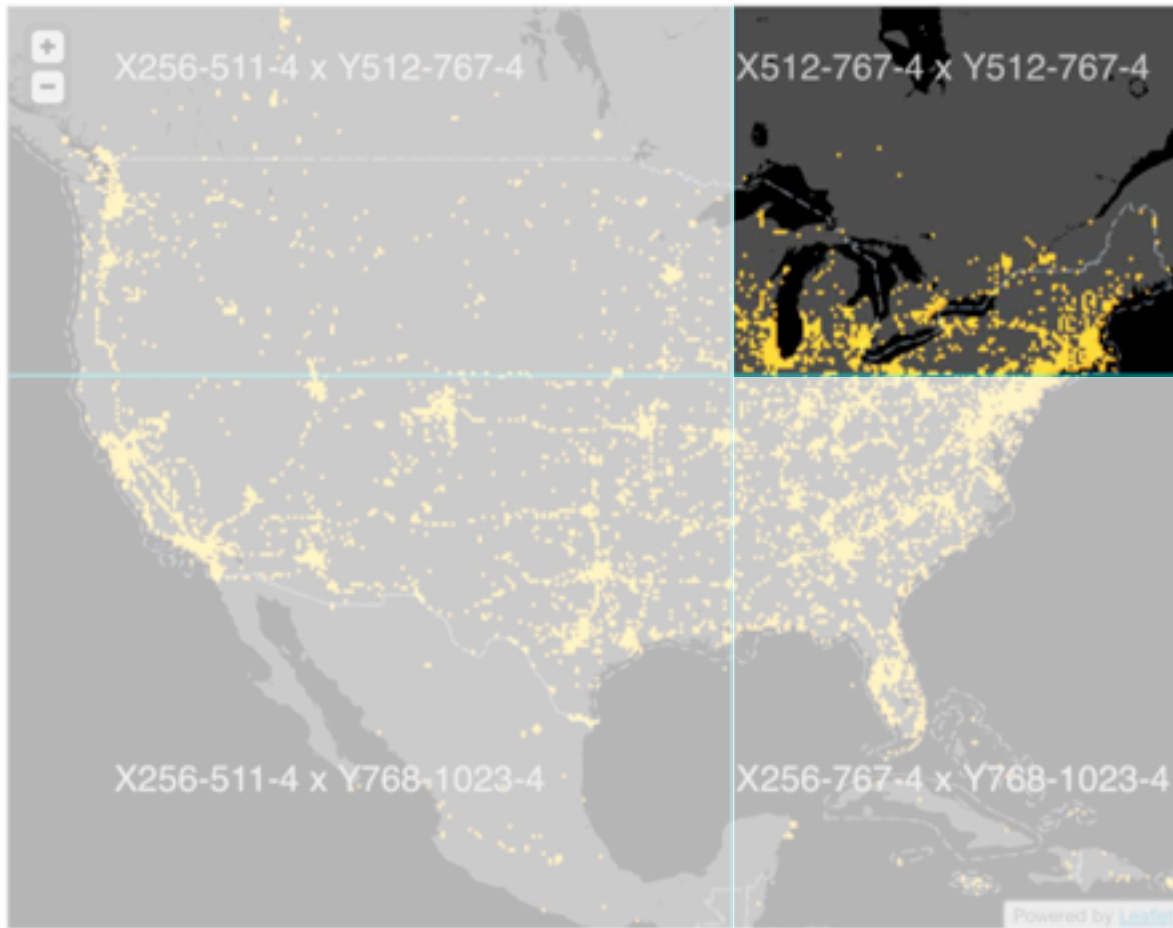


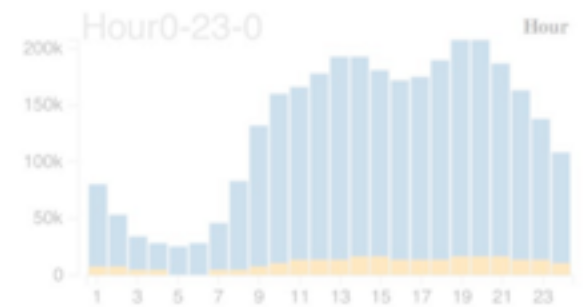
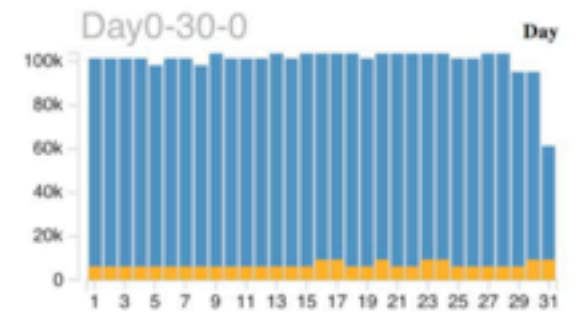
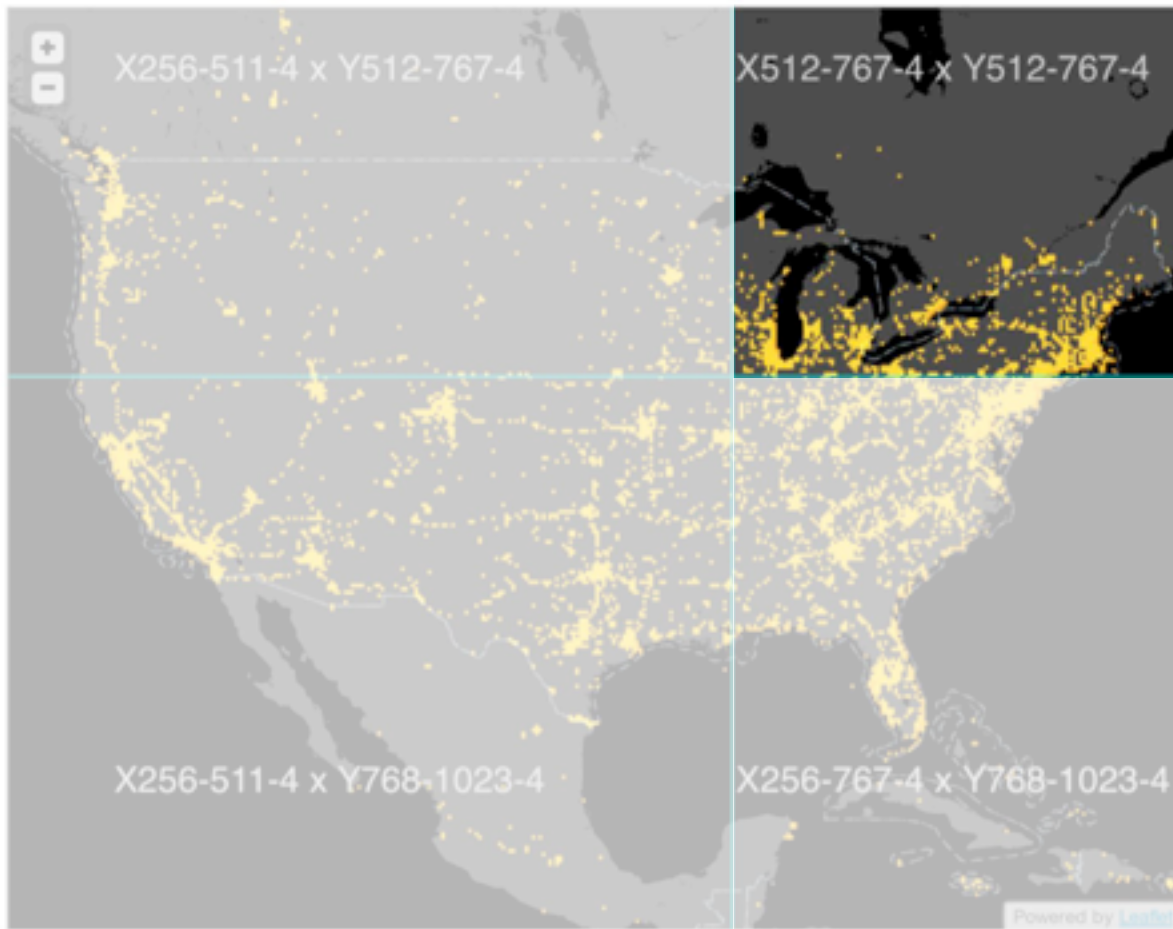


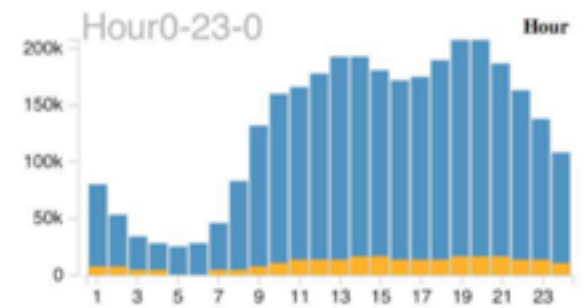
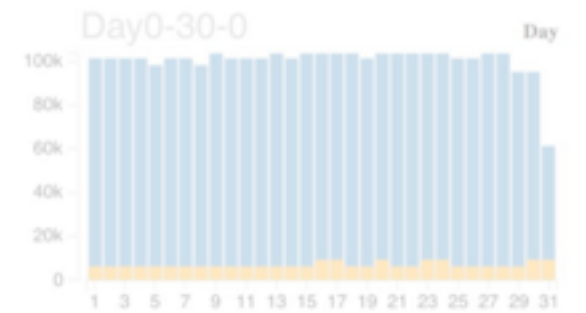
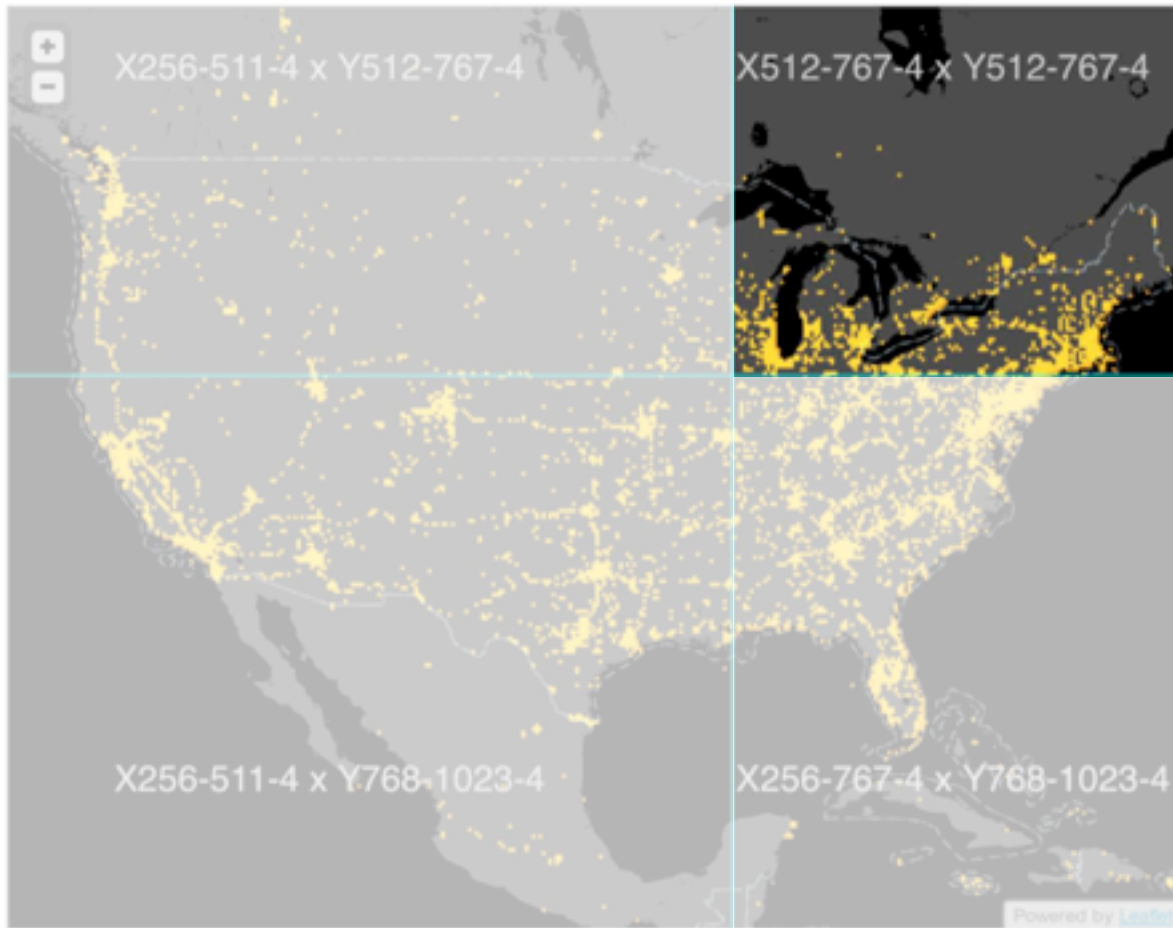


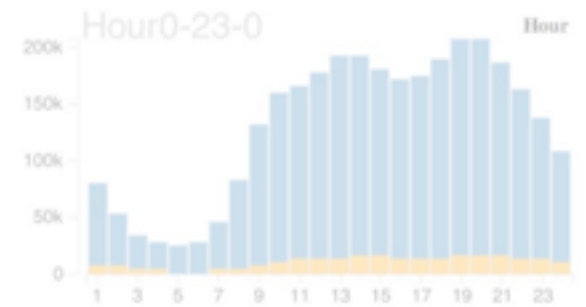
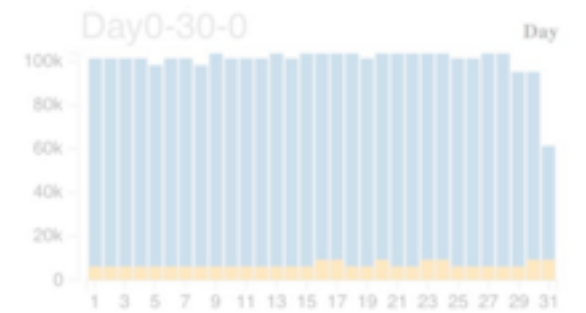
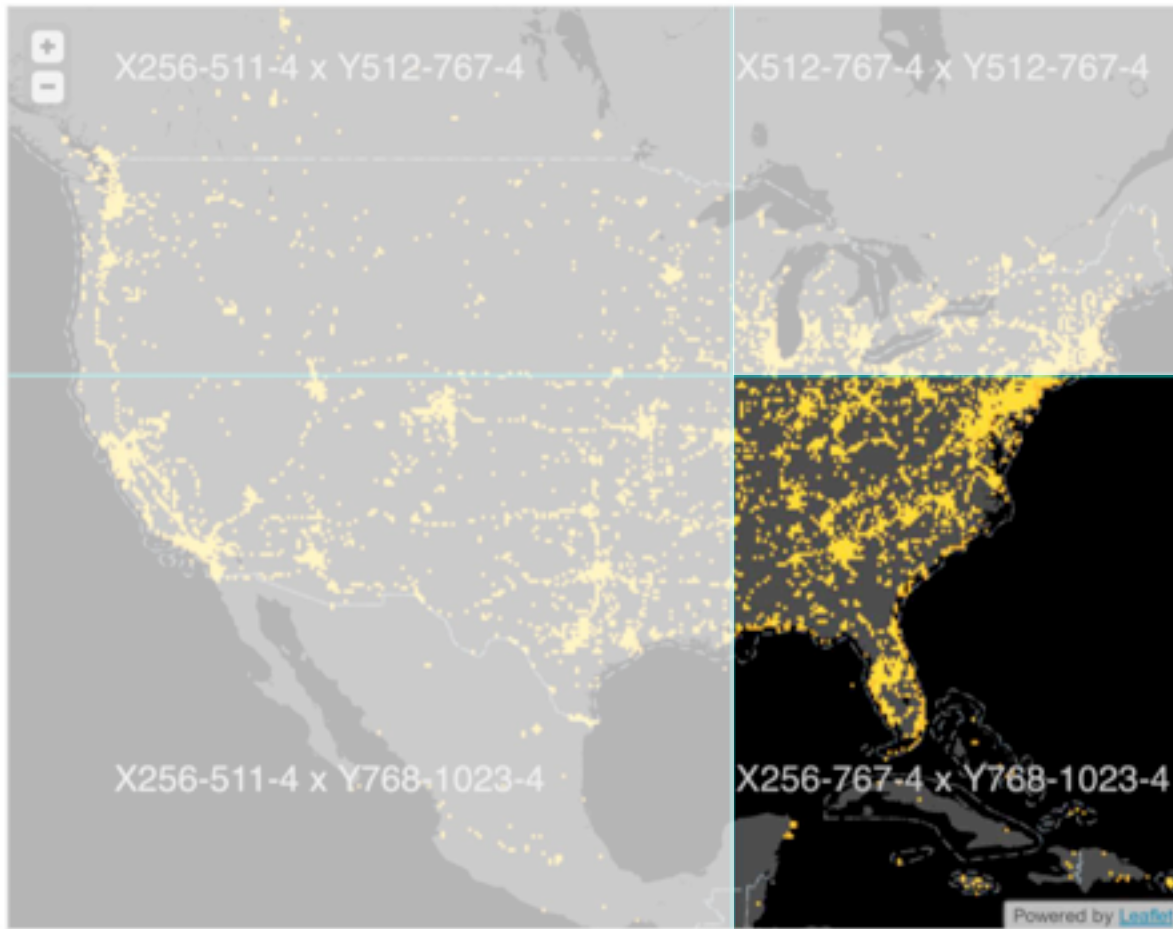


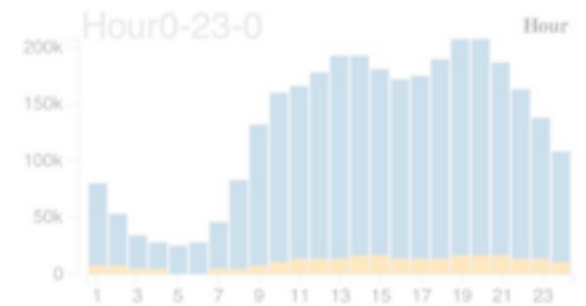
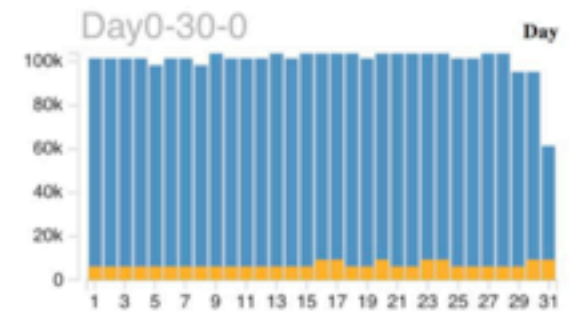
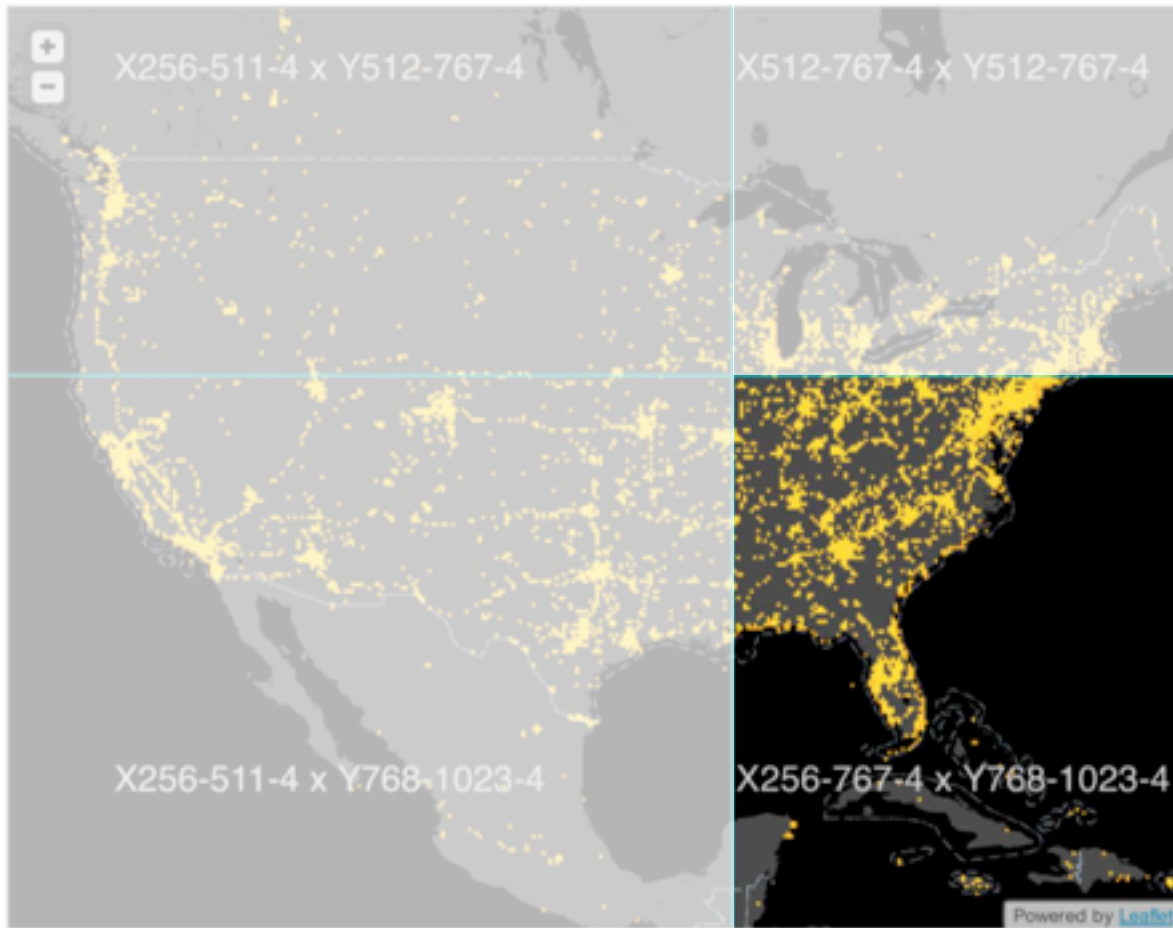


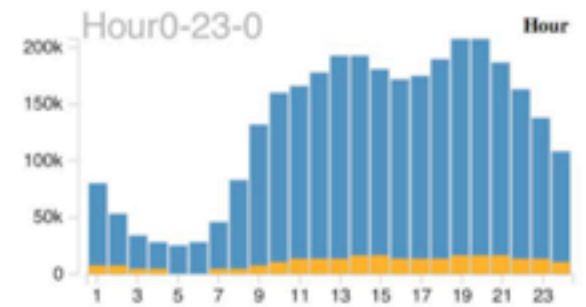
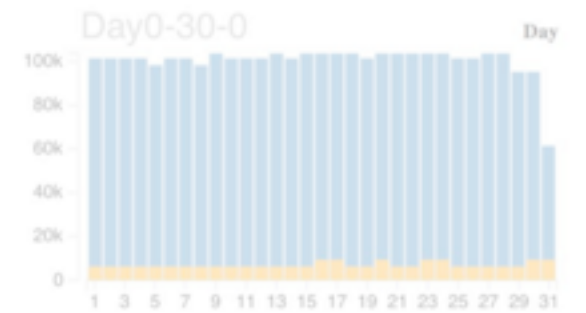
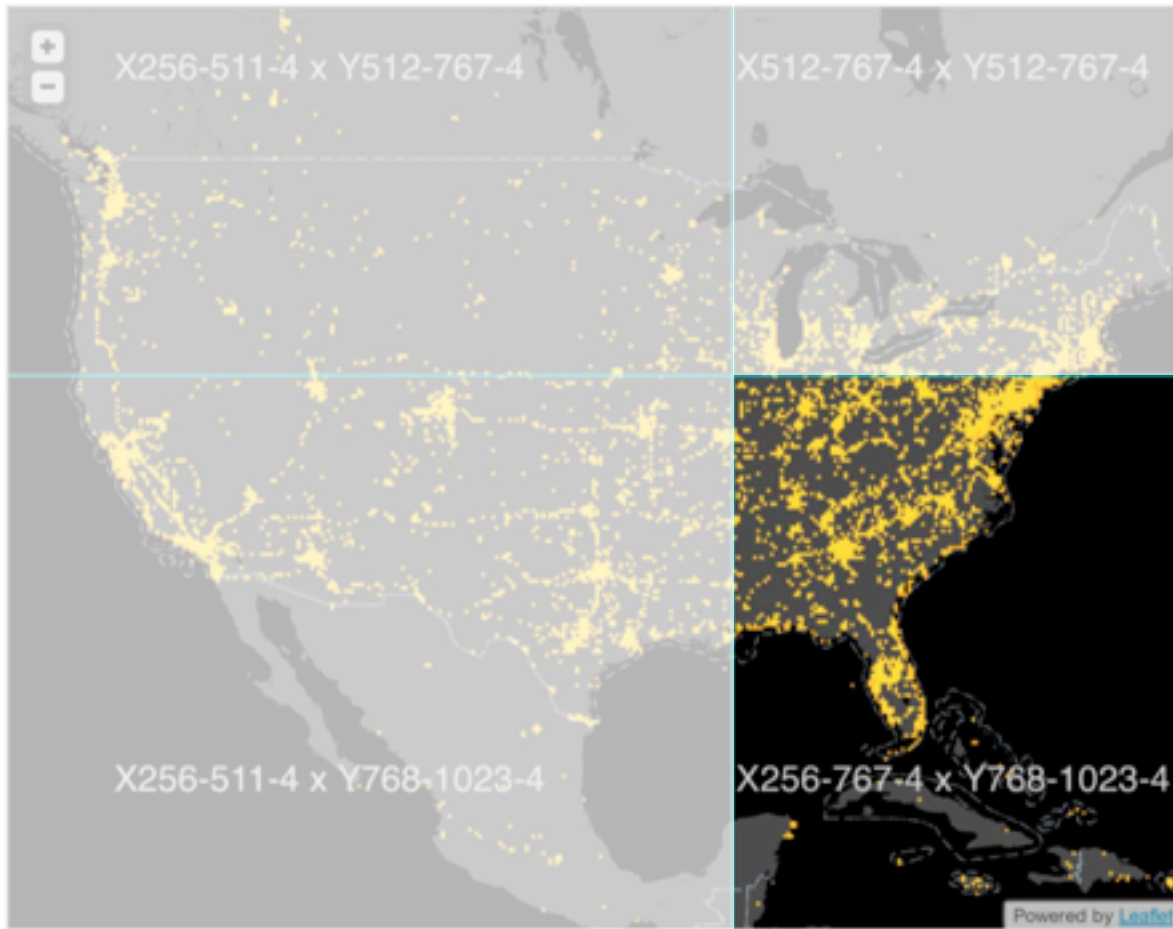


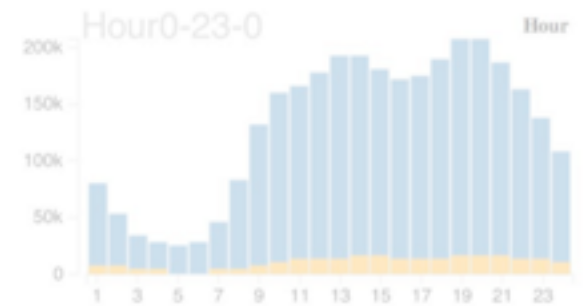
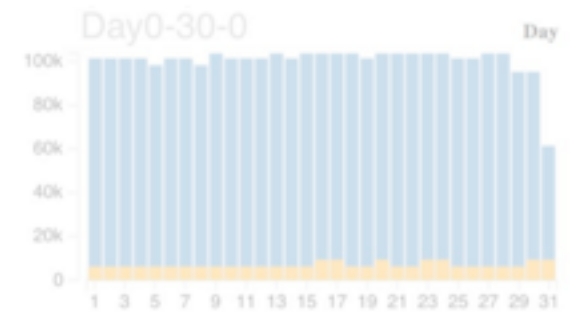
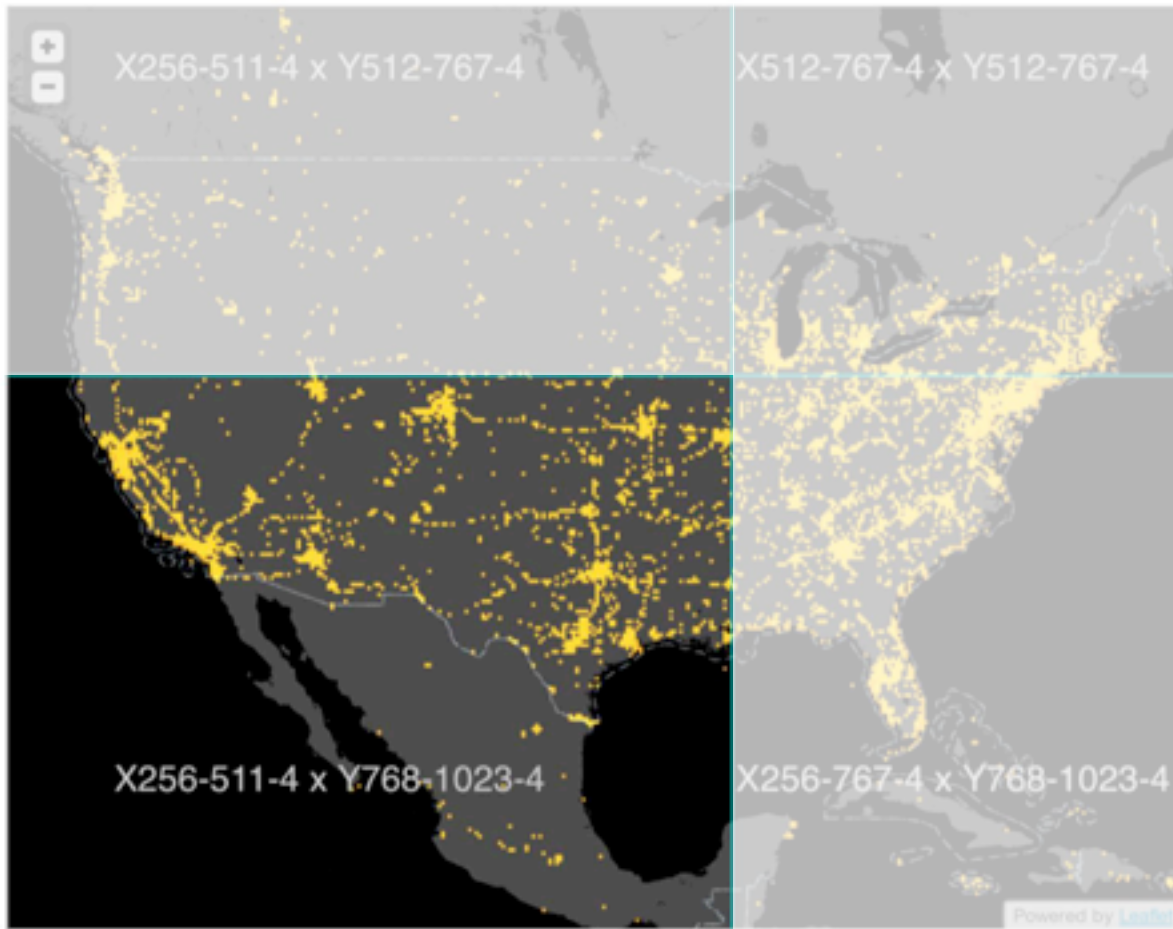


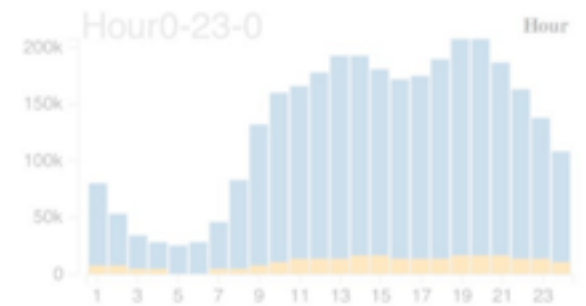
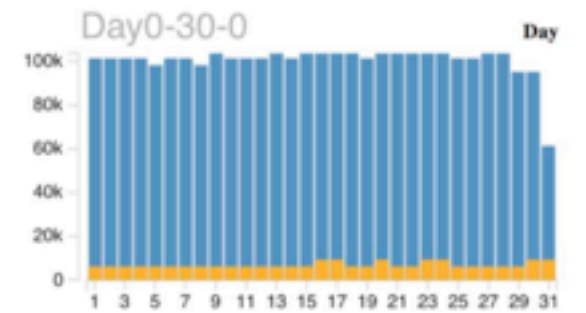
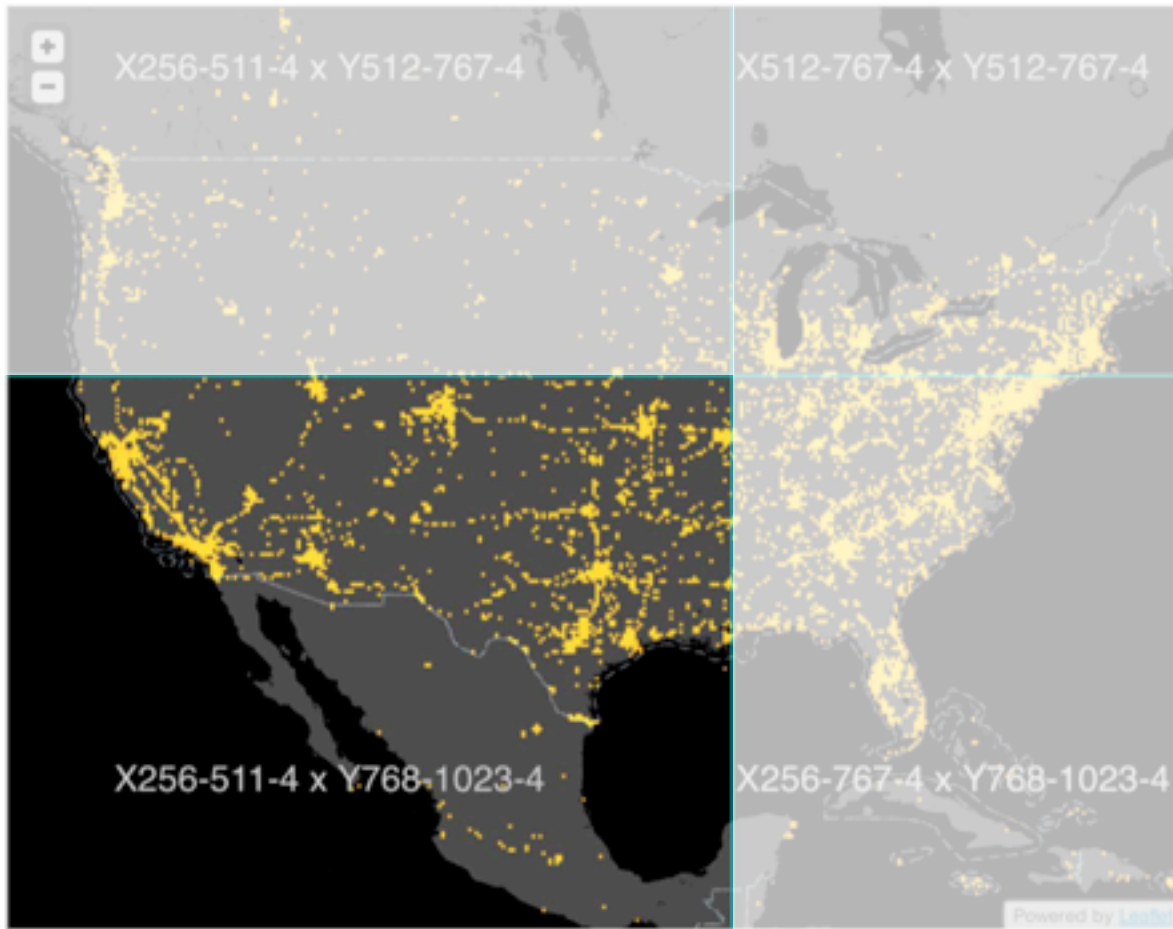


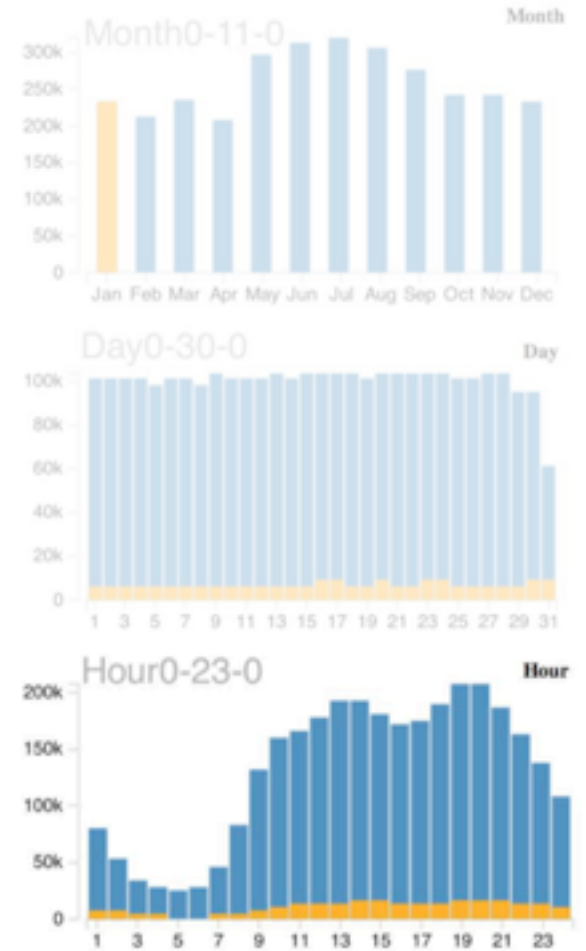
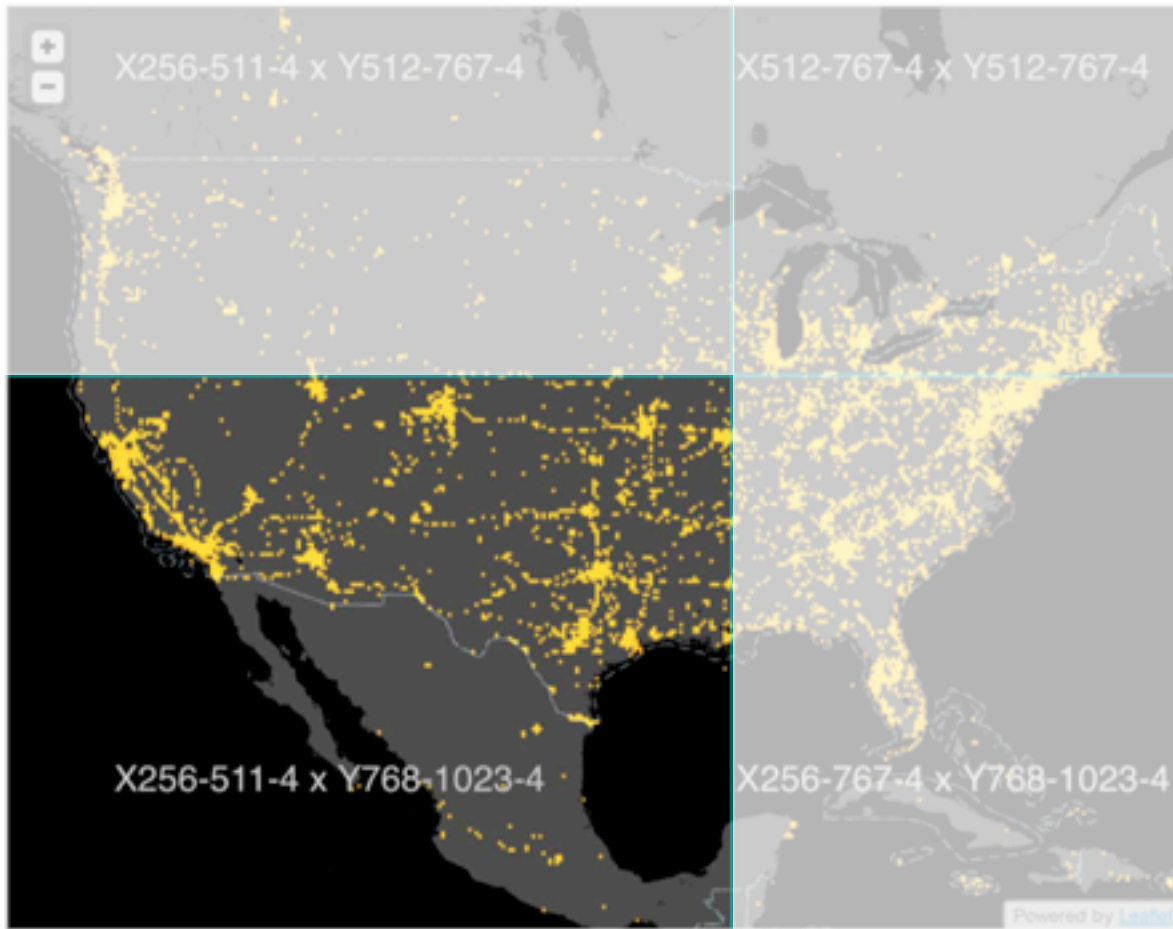


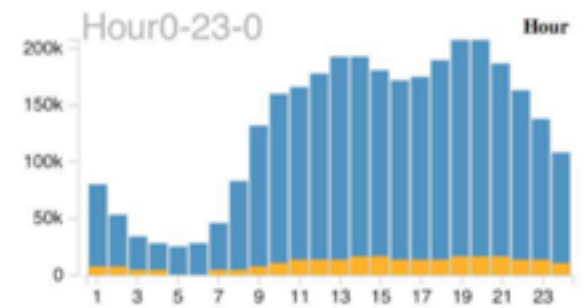
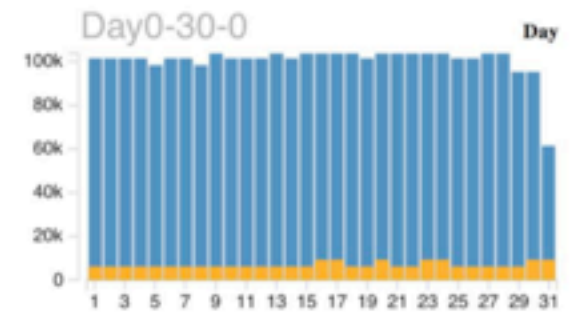
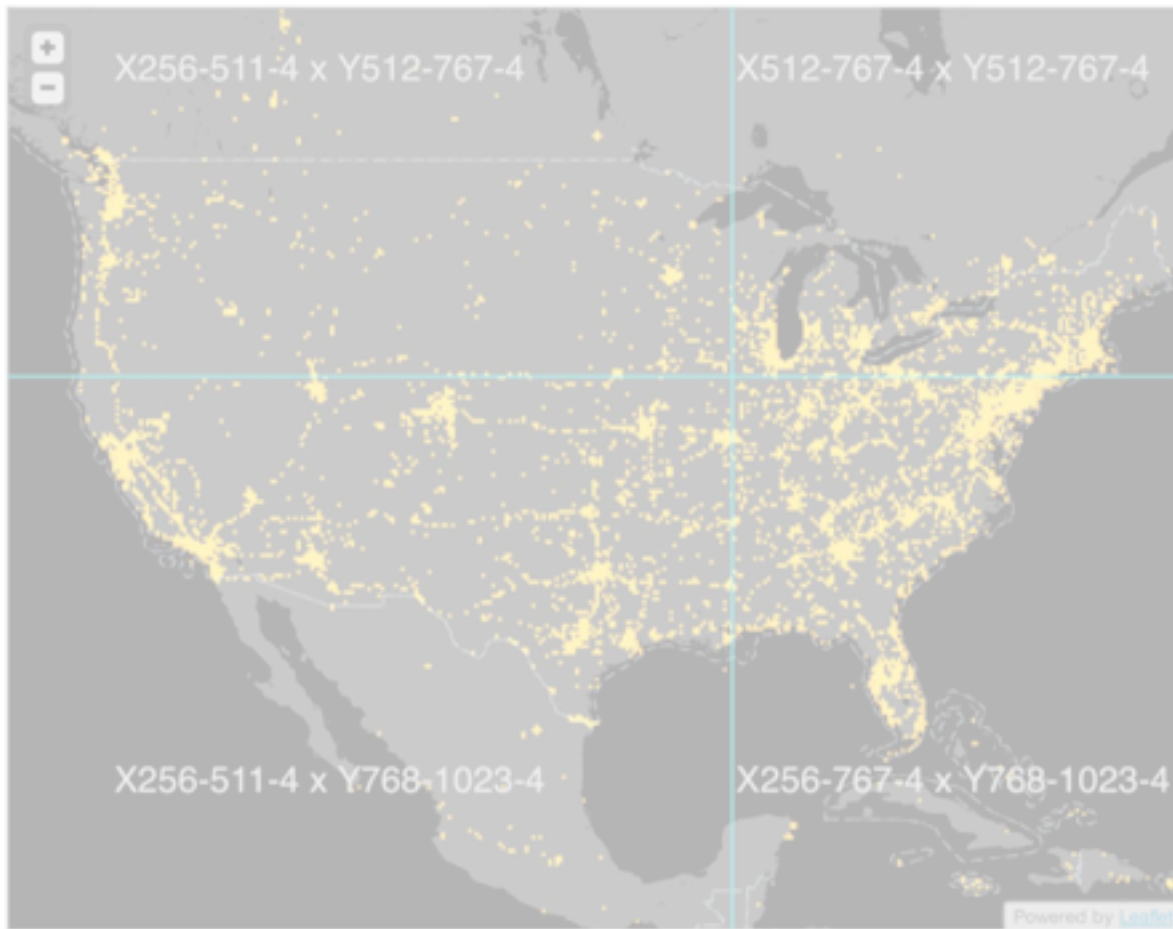


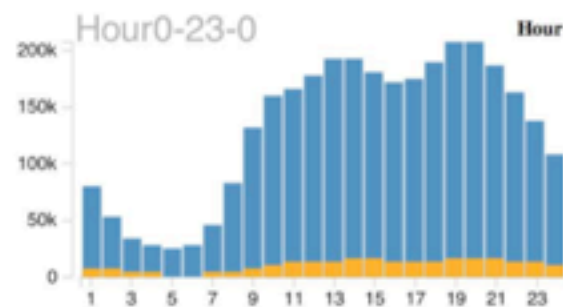
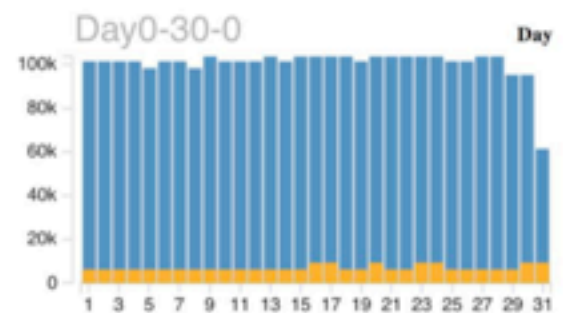
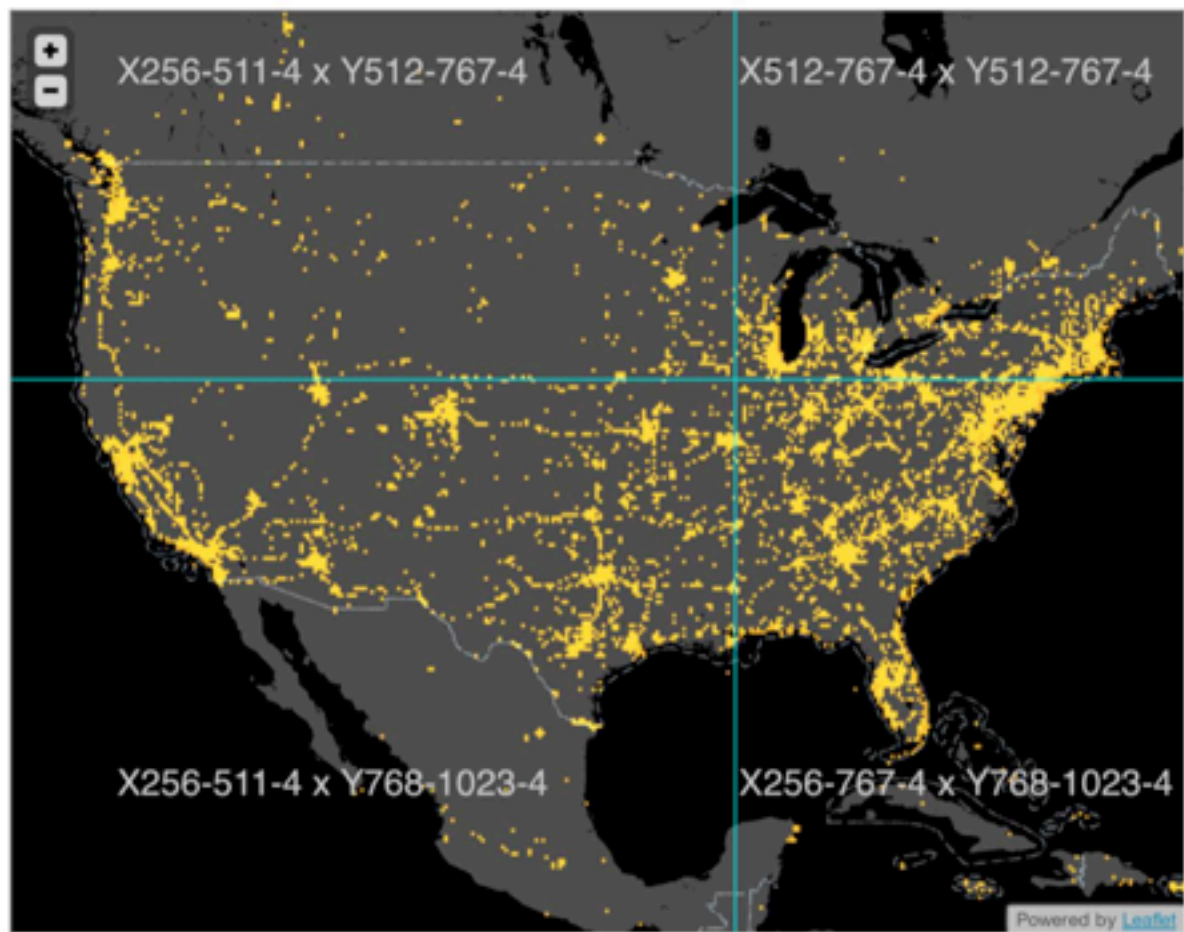




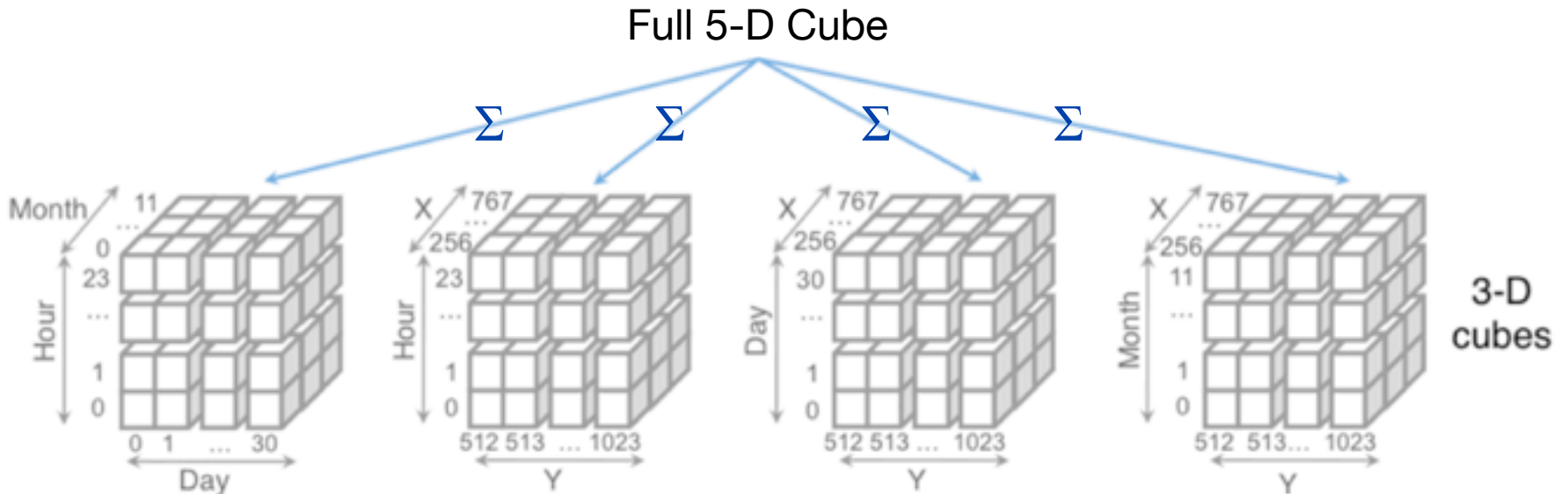






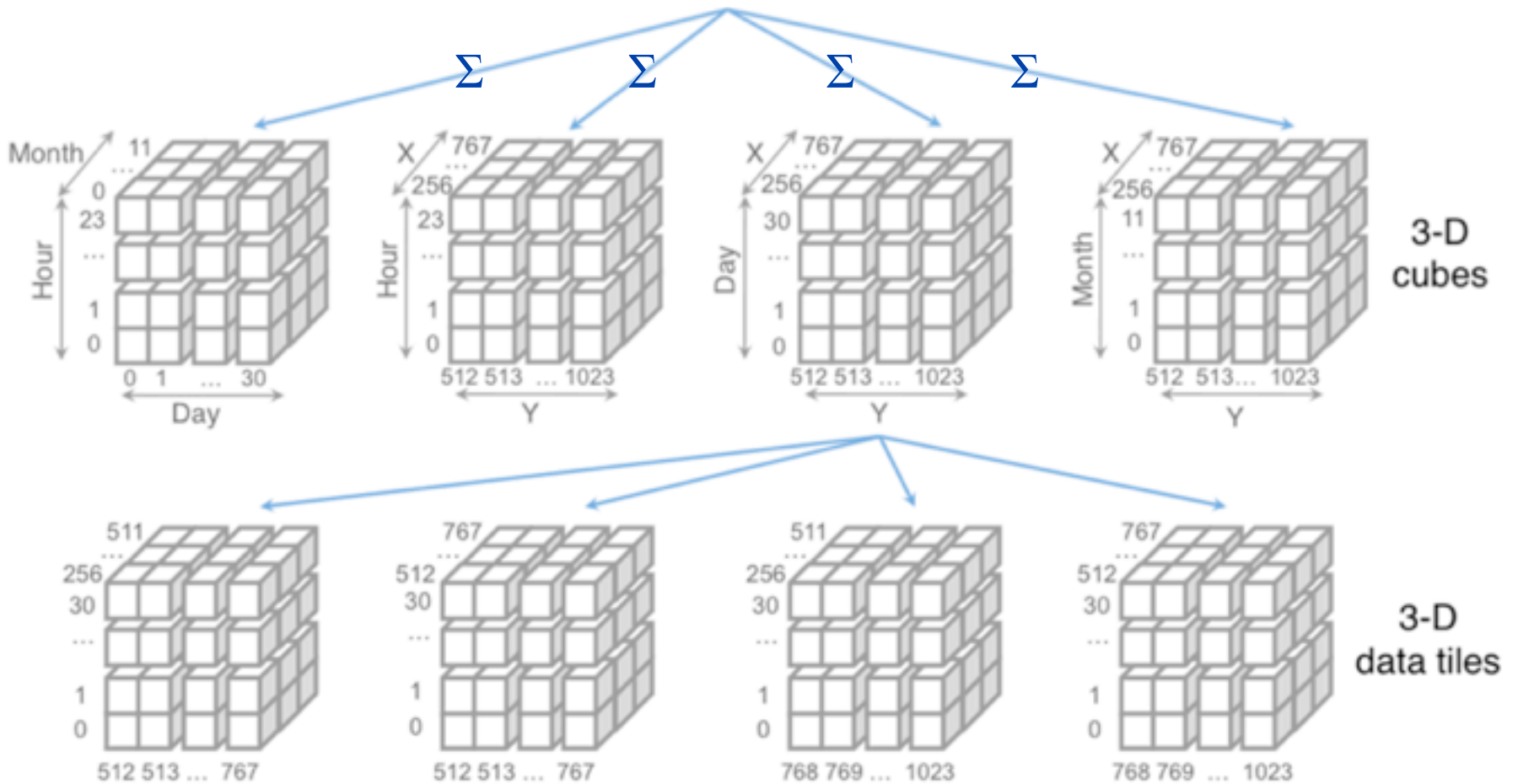


Full 5-D Cube

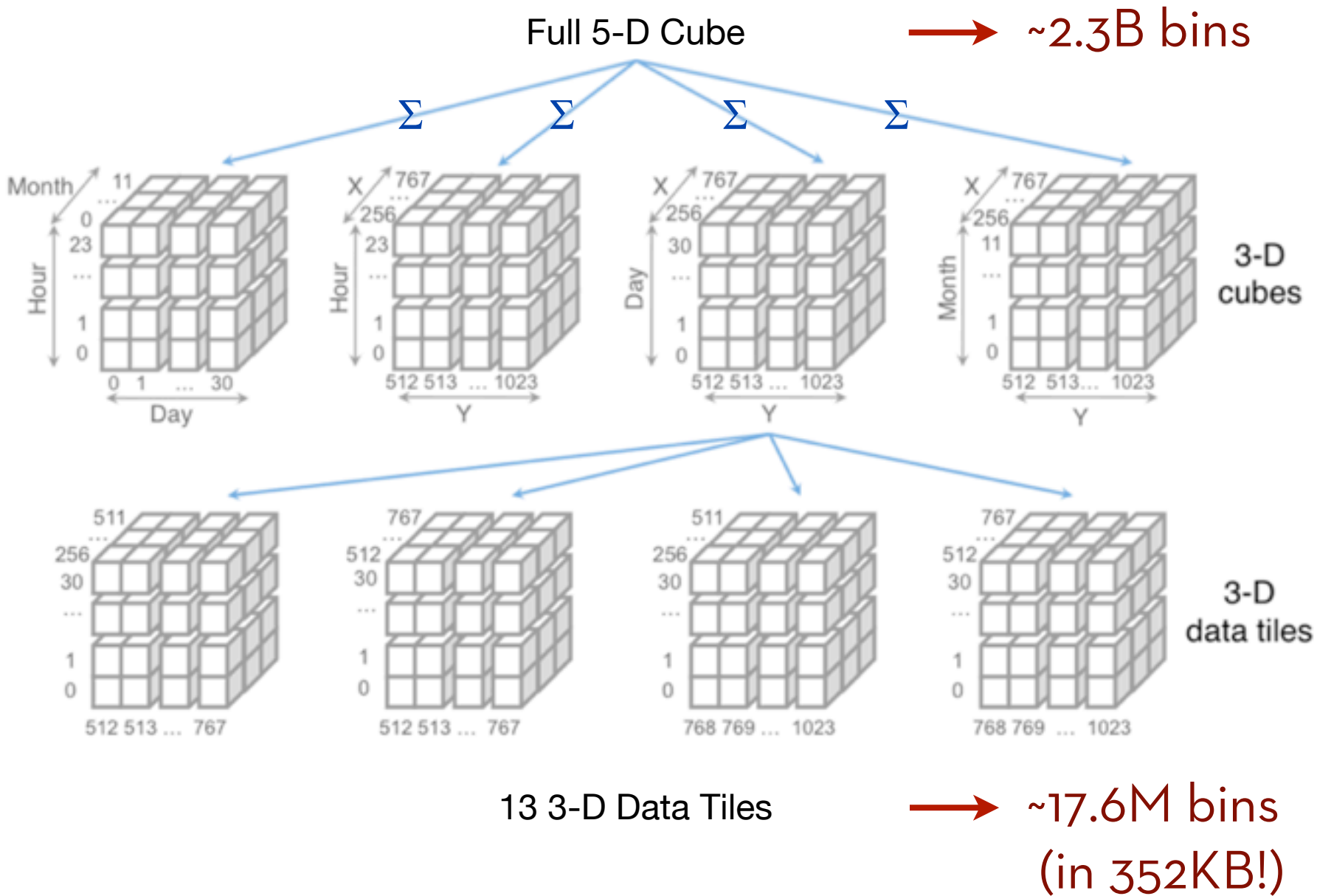


For any pair of 1D or 2D binned plots, the maximum number of dimensions needed to support brushing & linking is **four**.

Full 5-D Cube



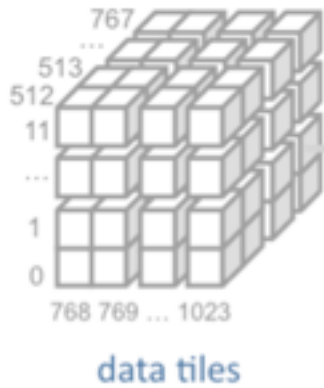
13 3-D Data Tiles



Multivariate Data Tiles

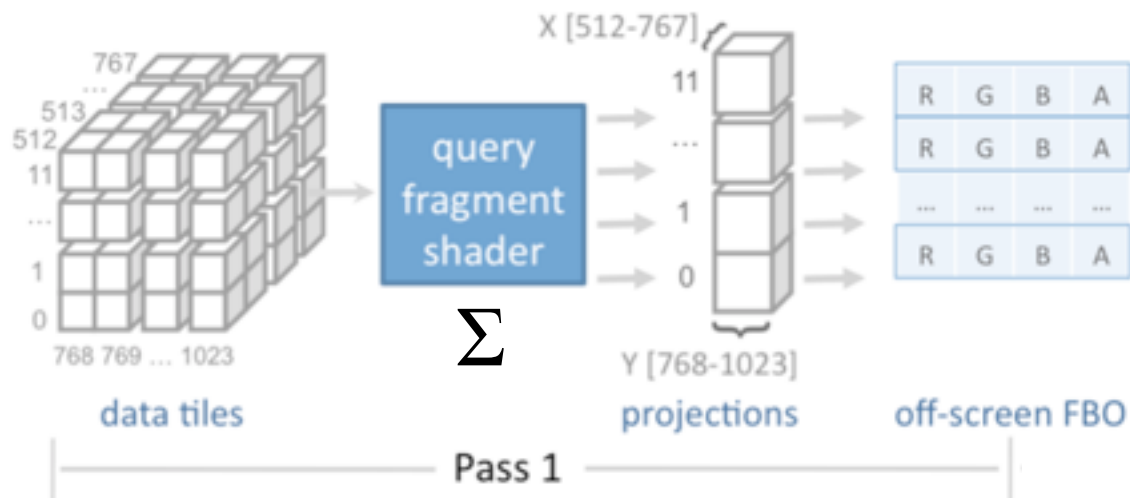
1. Send data, not pixels
2. Embed multi-dim data
3. Parallelize queries (GPU)

Query & Render on GPU via WebGL



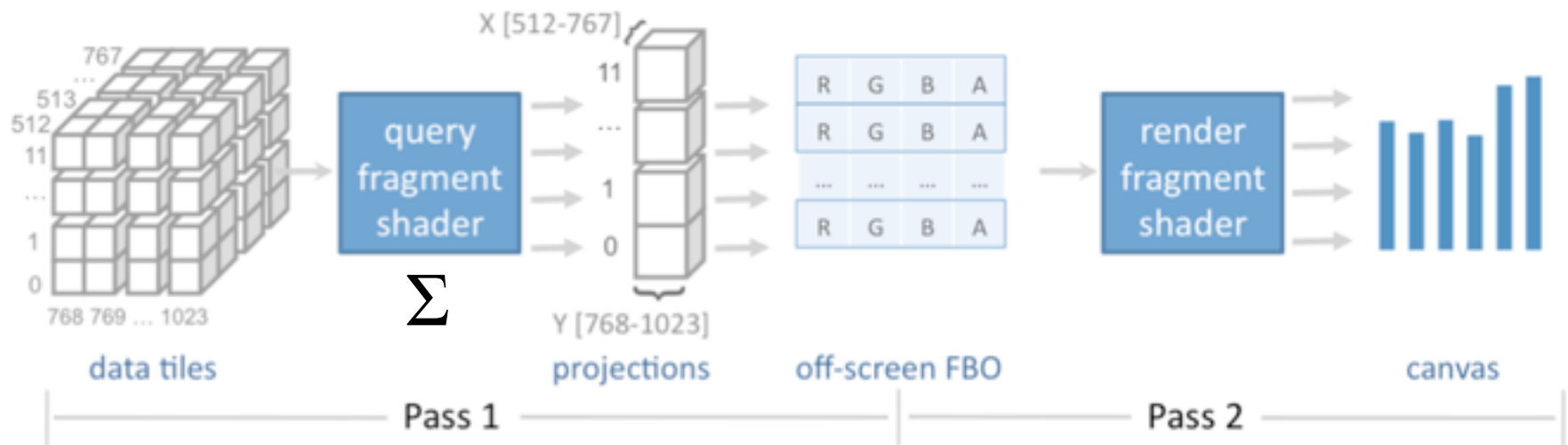
Pack data tiles as PNG image files,
bind to WebGL as image textures.

Query & Render on GPU via WebGL



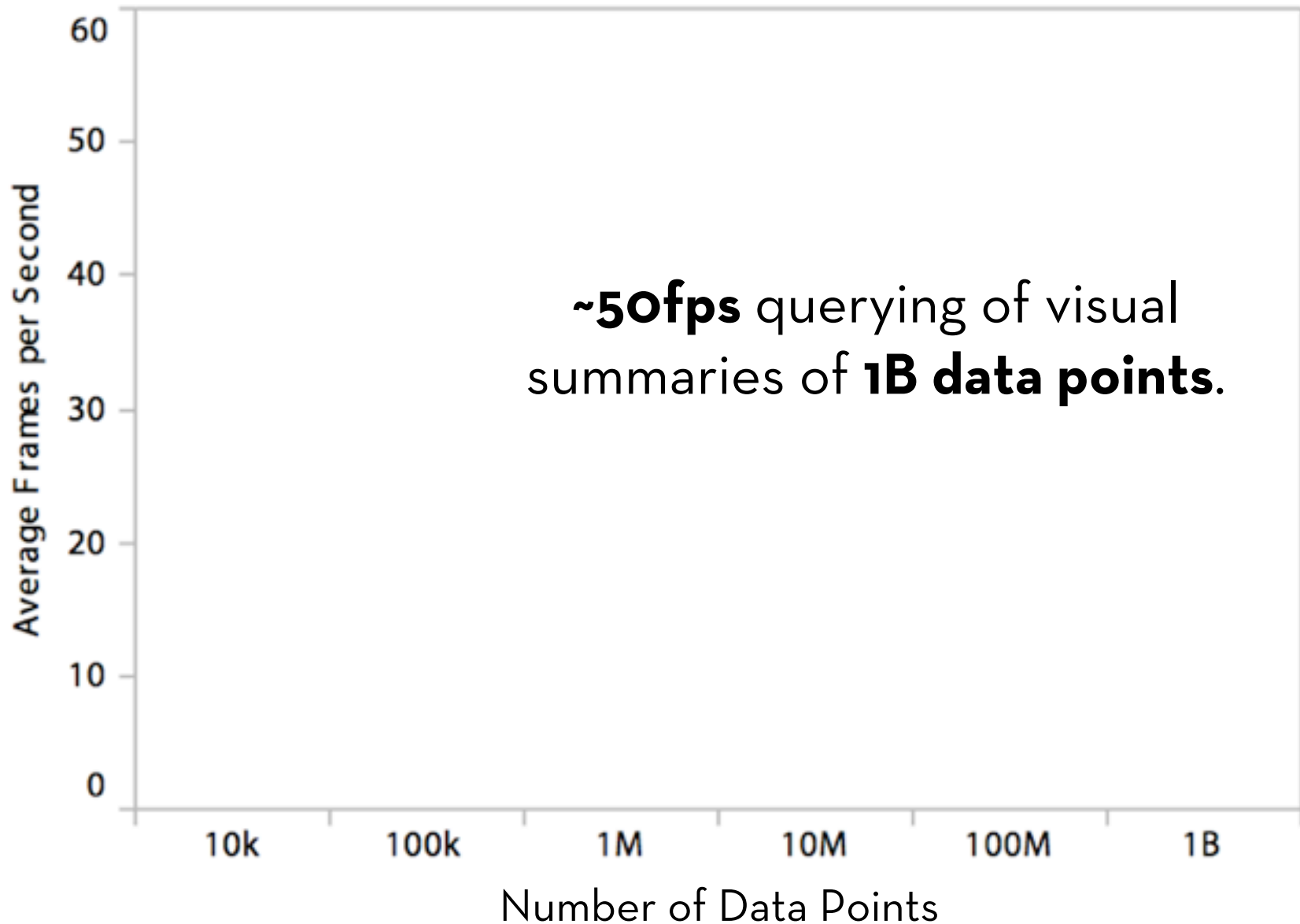
Compute aggregation for each output bin.
Executes in parallel on GPU.

Query & Render on GPU via WebGL



Accumulate results in offscreen buffer.
Render resulting plots in second pass.

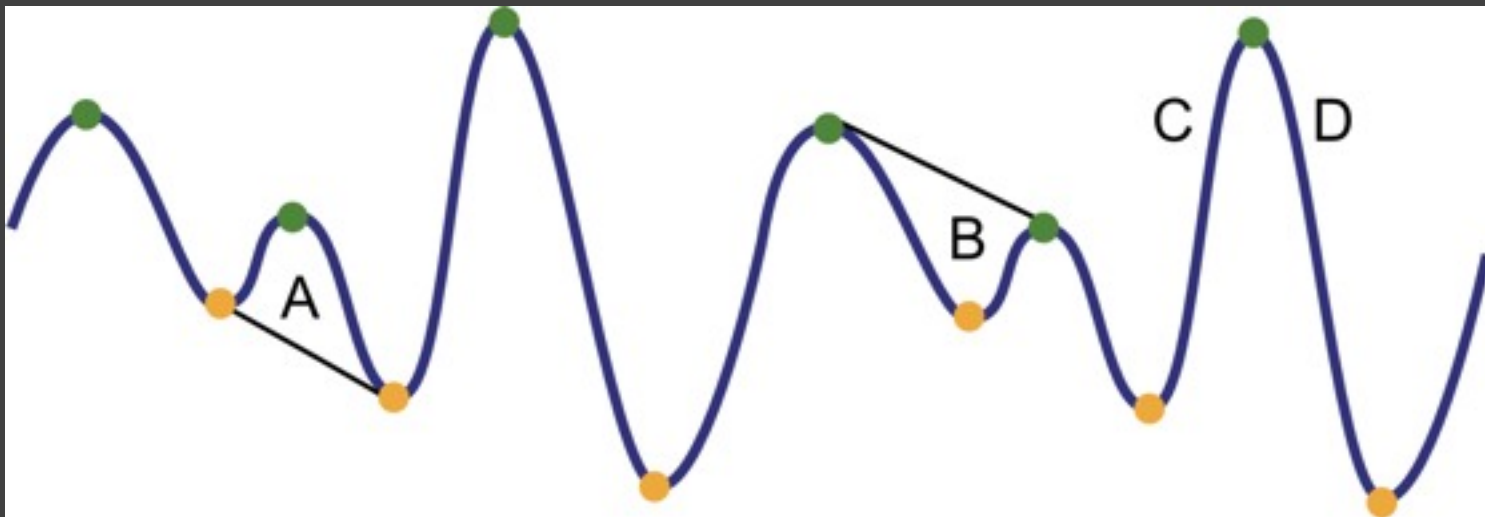
5 dimensions x 50 bins/dim x 25 plots



Parting Thoughts

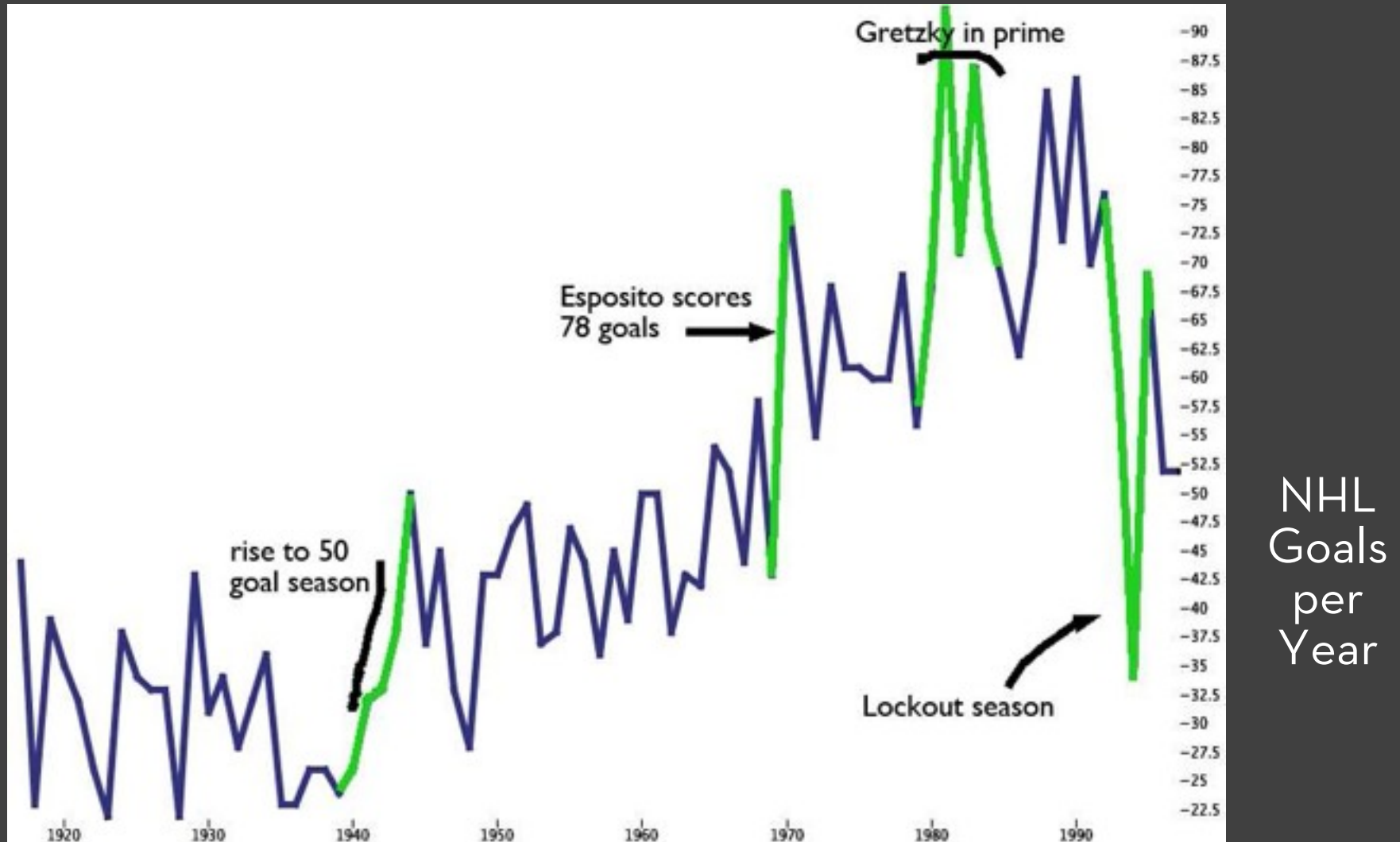
Consider how the structure and/or semantics of the data might be leveraged to aid analysis.

One idea: look beyond data features to incorporate perceptual features of the display.



Peaks,
valleys,
& slopes

Perceptual Annotation [Kong & Agrawala 09]



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