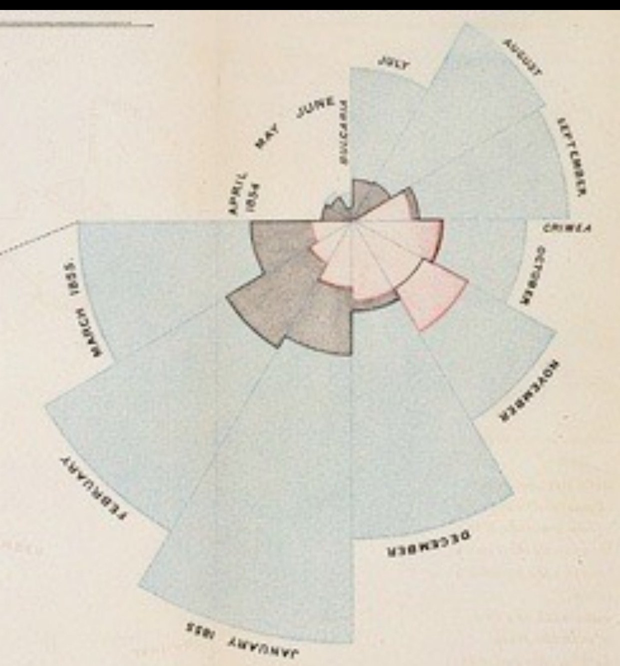
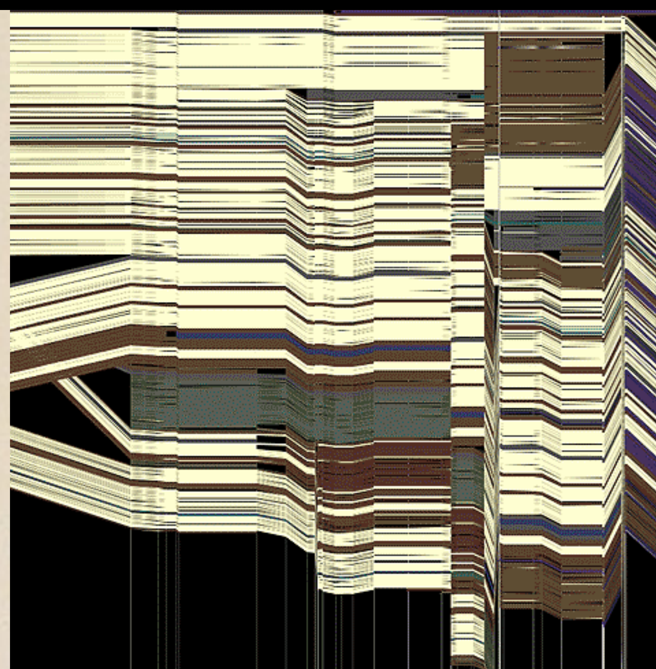
CSE 512 - Data Visualization

Visualization Tools






Jeffrey Heer University of Washington

How do people create visualizations?

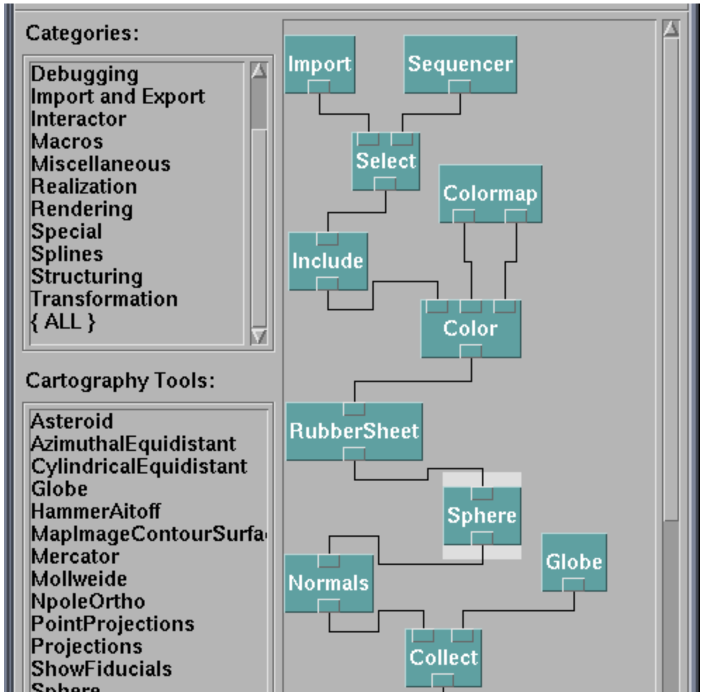


Chart Typology

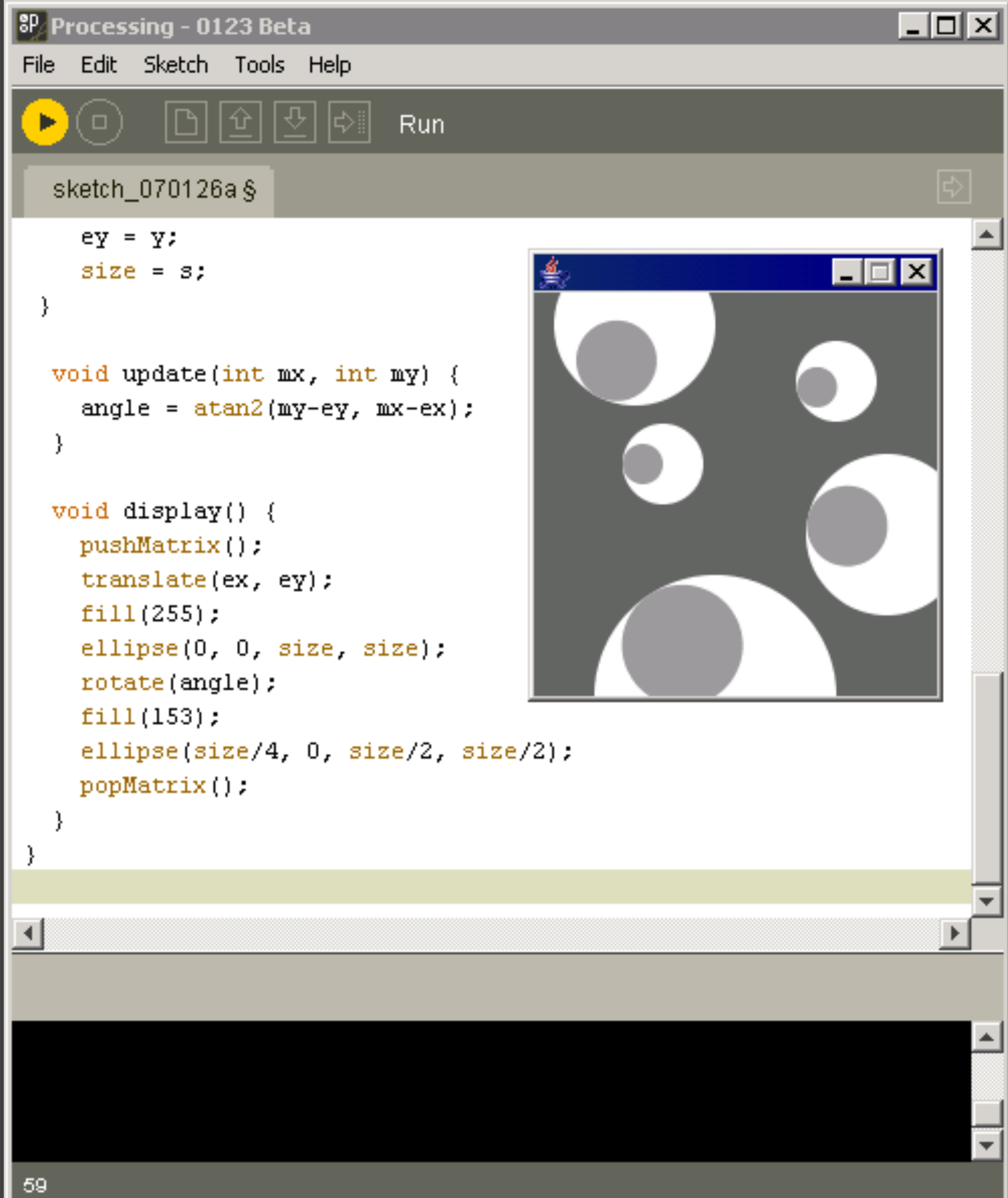
Pick from a stock of templates
Easy-to-use but limited expressiveness
Prohibits novel designs, new data types

Component Architecture

Permits more combinatorial possibilities
Novel views require new operators,
which requires software engineering

Graphics APIs

Processing, OpenGL, Java2D



http://processing.org

US Air Traffic, Aaron Koblin

Graphics APIs

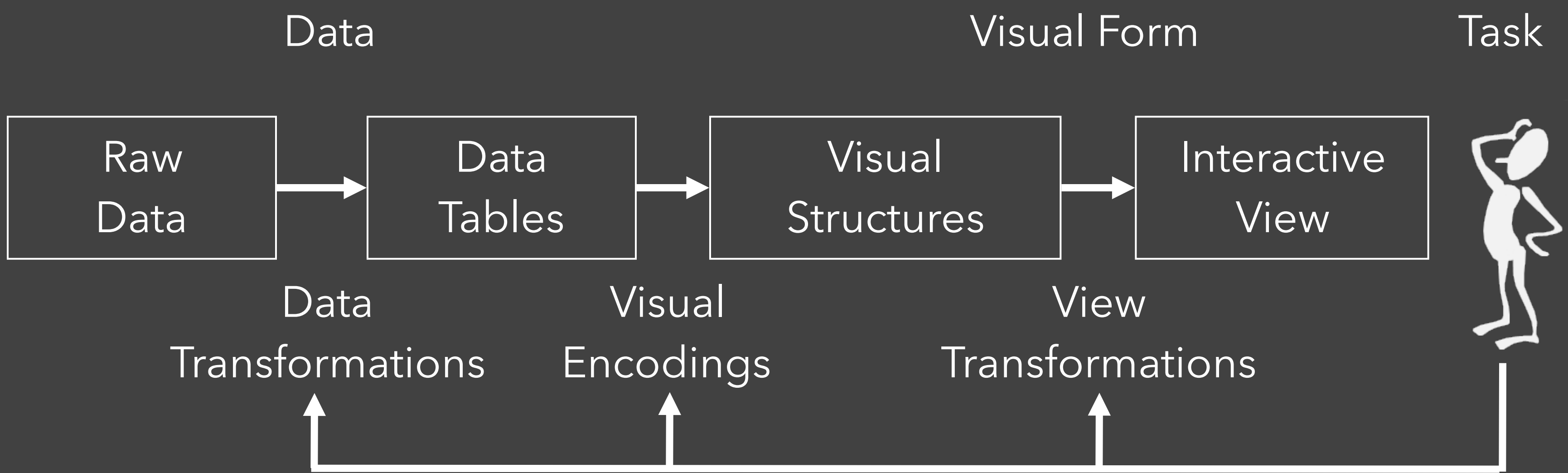
Processing, OpenGL, Java2D

Component Architectures

Prefuse, Flare, Improvise, VTK

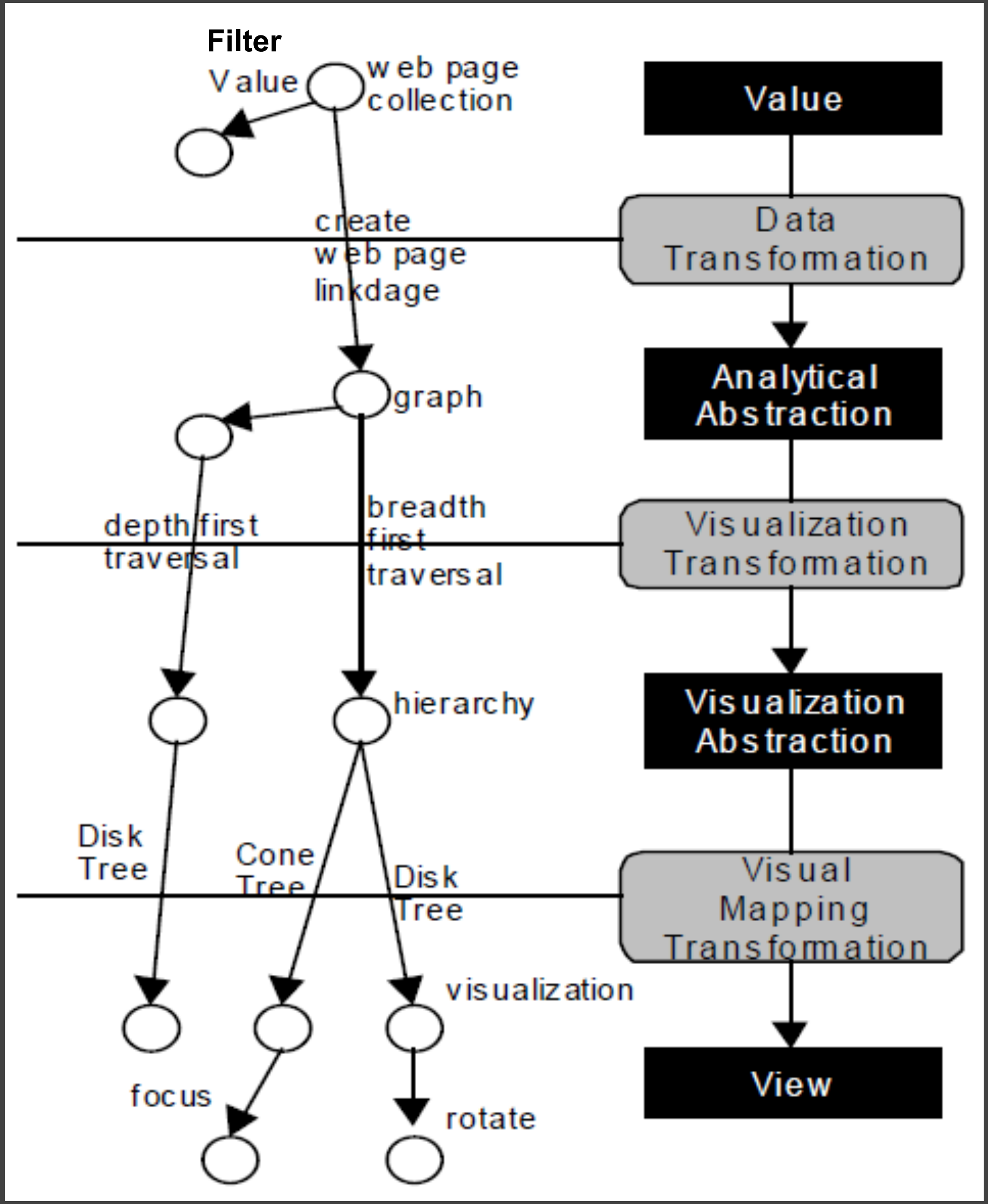
Graphics APIs

Processing, OpenGL, Java2D


Data
Visual Form
Task
Raw Data
Data Tables
Visual Structures
Interactive View
Data Transformations
Visual Encodings
View Transformations

Data State Model

[Chi 98]



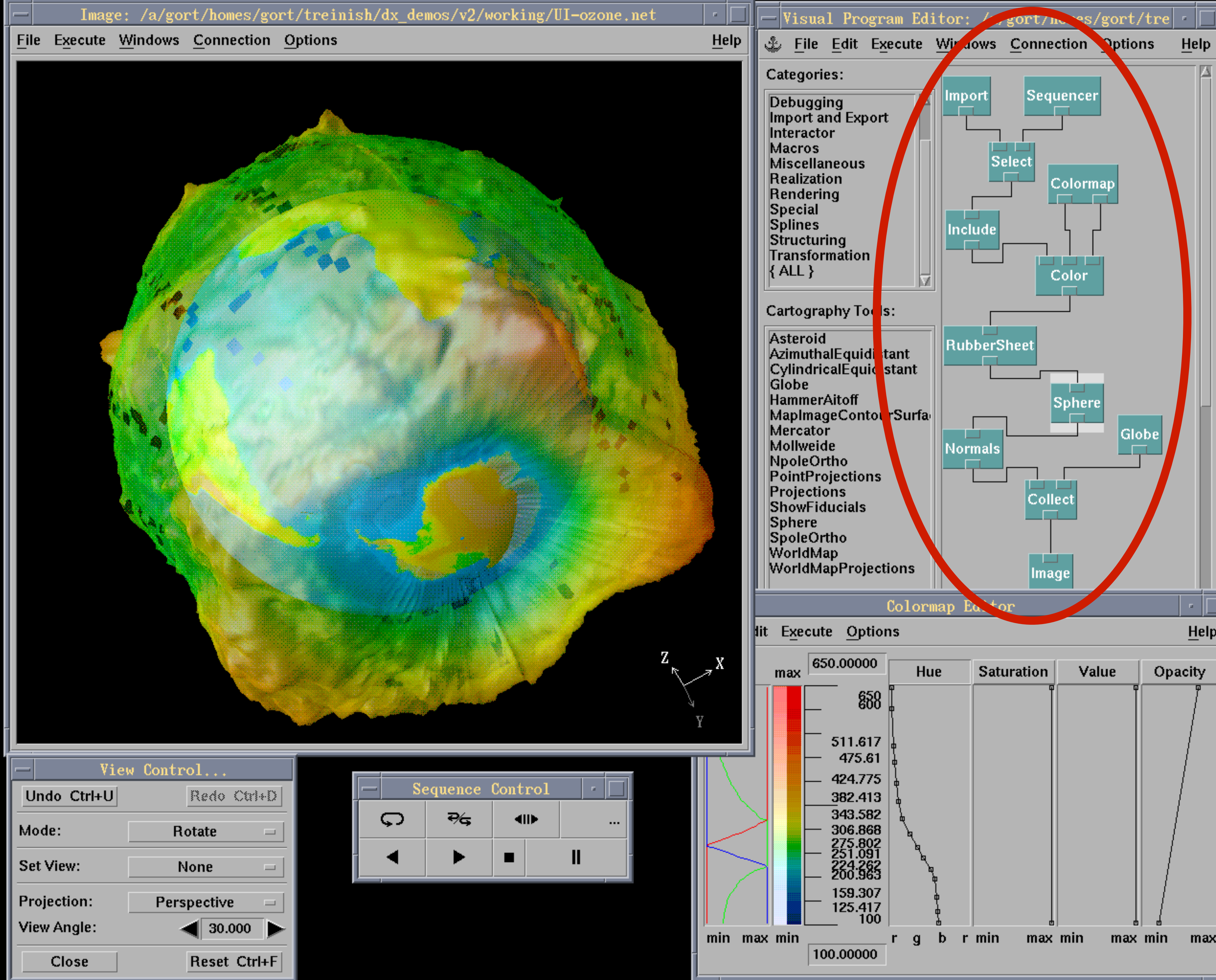
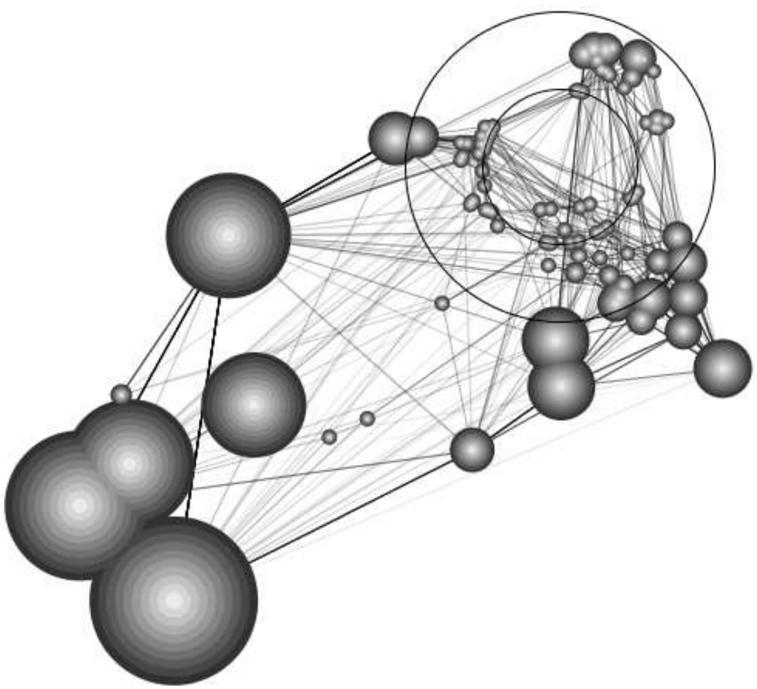


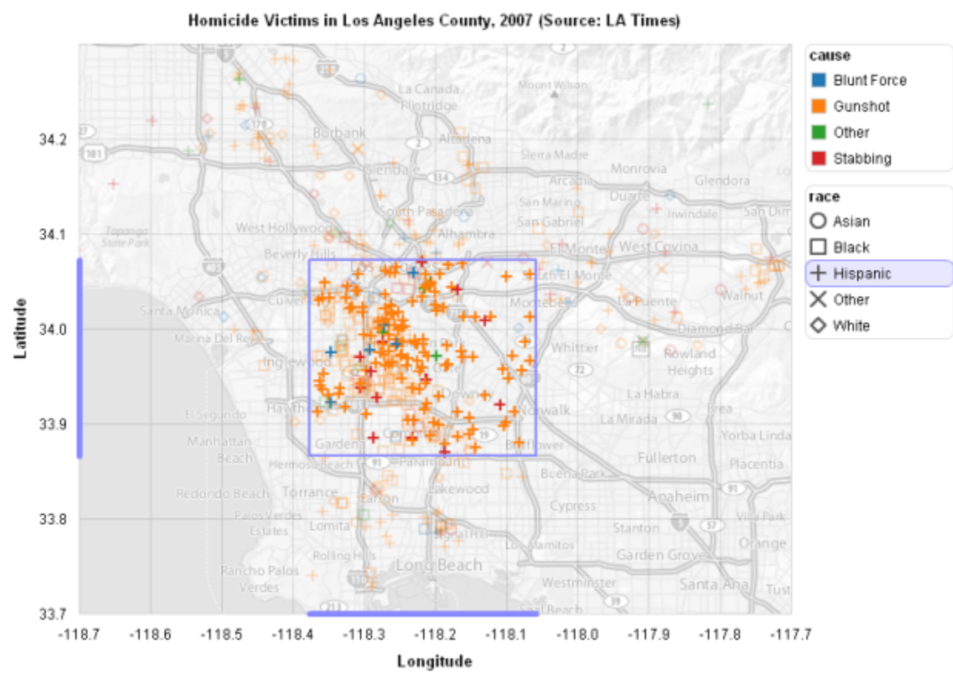
Image: /a/gort/homes/gort/treinish/dx_demos/v2/working/UI-ozone.net
File Execute Windows Connection Options Help
Visual Program Editor: /a/gort/homes/gort/tre
File Edit Execute Windows Connection Options Help
Categories:
Debugging
Import and Export
Interactor
Macros
Miscellaneous
Realization
Rendering
Special
Splines
Structuring
Transformation
{ ALL }
Cartography Tools:
Asteroid
AzimuthalEquidistant
CylindricalEquidistant
Globe
HammerAitoff
MapImageContourSurfa
Mercator
Mollweide
NpoleOrtho
PointProjections
Projections
ShowFiducials
Sphere
SpoleOrtho
WorldMap
WorldMapProjections
Import
Sequencer
Select
Colormap
Include
Color
RubberSheet
Sphere
Globe
Normals
Collect
Image
Colormap Editor
Execute Options Help
max
650.00000
Hue
Saturation
Value
Opacity
650
600
511.617
475.61
424.775
382.413
343.582
306.868
275.802
251.091
224.262
200.963
159.307
125.417
100
min max min
r g b
r min max min max min max
100.00000
View Control...
Undo Ctrl+U
Redo Ctrl+D
Mode: Rotate
Set View: None
Projection: Perspective
View Angle: 30.000
Close
Reset Ctrl+F
Sequence Control
Z
X
Y

Prefuse & Flare

Operator-based toolkits for visualization design

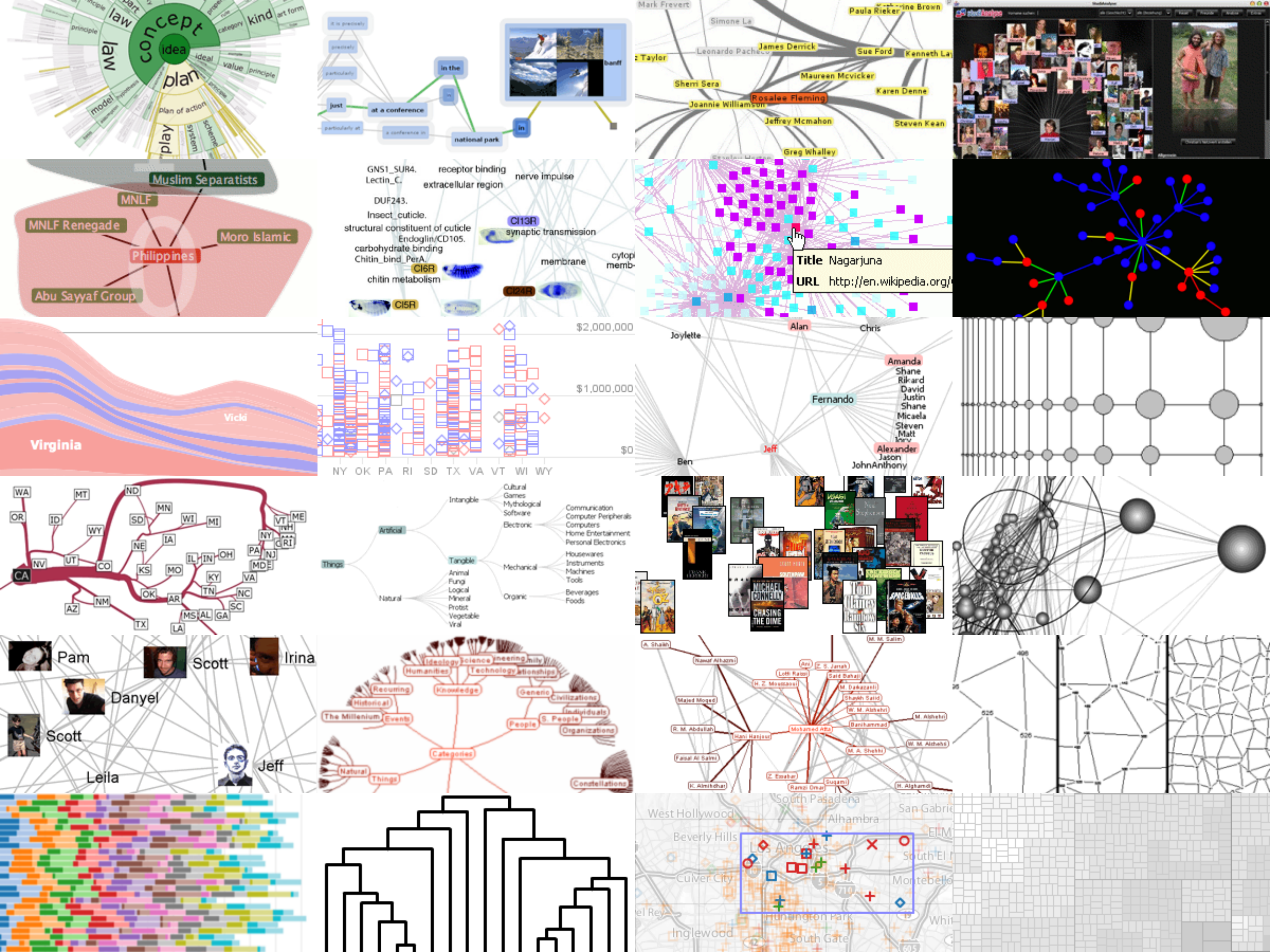
Vis = (Input Data -> Visual Objects) + Operators



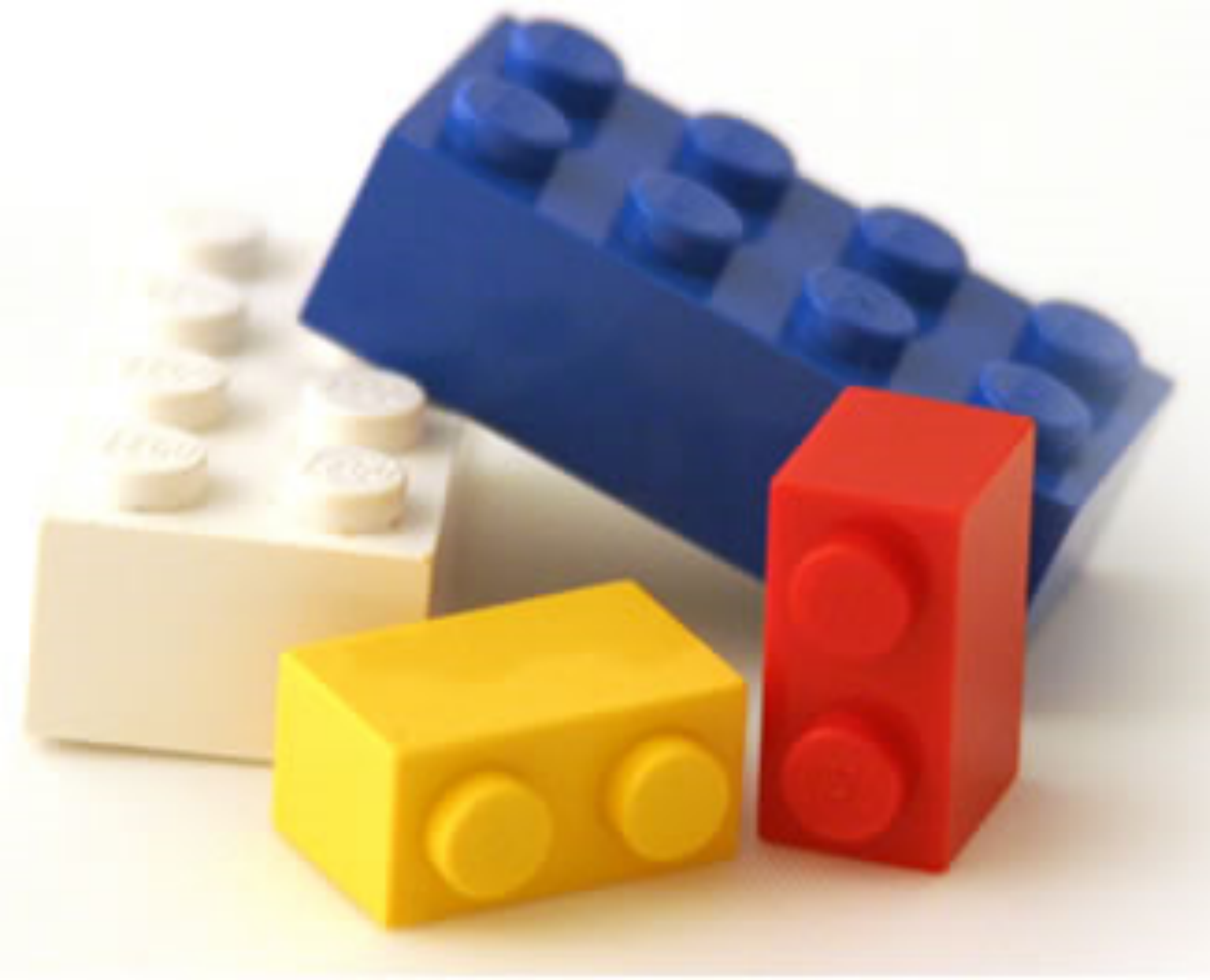


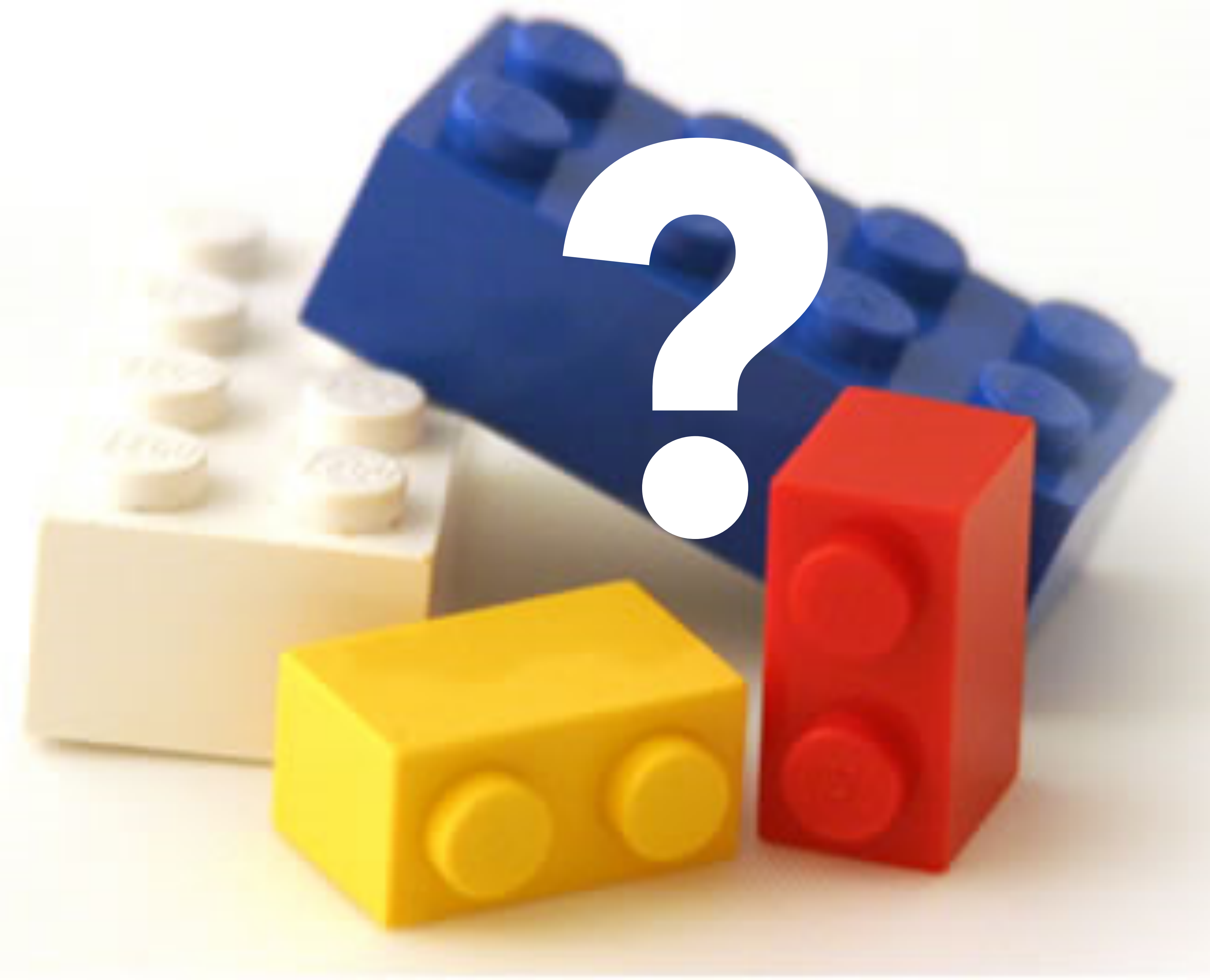
Prefuse (http://prefuse.org)

Flare (http://flare.prefuse.org)



concept
idea
law
kind
plan
plan of action
play
system
ideal
value
principle
at a conference
national park
in the
just
banff
Paula Rieker
Simone La
James Derrick
Sue Ford
Kenneth Lay
Maureen Mcvicker
Sherri Sera
Rosalee Fleming
Karen Denne
Joannie Williamson
Jeffrey Mcmahon
Steven Kean
Greg Whalley
Muslim Separatists
MNLF
MNLF Renegade
Moro Islamic
Philippines
Abu Sayyaf Group
GNS1_SUR4.
receptor binding
nerve impulse
Lectin_C.
extracellular region
DUF243.
Insect_cuticle.
structural constituent of cuticle
Endoglin/CD105.
carbohydrate binding
Chitin_bind_PerA.
chitin metabolism
synaptic transmission
membrane
CI3R
CI6R
CI5R
Title Nagarjuna
URL http://en.wikipedia.org/
Vicki
Virginia
$2,000,000
$1,000,000
$0
NY OK PA RI SD TX VA VT WI WY
Joylette
Alan
Chris
Amanda
Shane
Rikard
David
Justin
Micaela
Steven
Matt
Fernando
Jeff
Alexander
Jason
JohnAnthony
Ben
WA
MT
ND
OR
ID
MN
SD
WI
MI
WY
NE
IA
NY
VT
NH
ME
RI
PA
NJ
UT
CO
IL
IN
OH
MD
NV
KS
MO
KY
VA
CA
OK
TN
NC
AR
SC
AZ
NM
MS
AL
GA
TX
LA
Things
Artificial
Tangible
Natural
Intangible
Electronic
Mechanical
Organic
Cultural
Games
Mythological
Software
Communication
Computer Peripherals
Computers
Home Entertainment
Personal Electronics
Housewares
Instruments
Machines
Tools
Beverages
Foods
Animal
Fungi
Logical
Mineral
Protist
Vegetable
Viral
MICHAEL CONNELLY
CHASING THE DIME
Pam
Scott
Irina
Danyel
Scott
Leila
Jeff
Humanities
Technology
Knowledge
Historical
The Millenium
Events
Generic
People
Categories
Natural
Things
Constellations
Mohamed Atta
West Hollywood
South Pasadena
Alhambra
Beverly Hills
Los Angeles
Culver City
Montebello
Inglewood
South Gate
Huntington Park





Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

Chart Typologies

Excel, Many Eyes, Google Charts

Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

Chart Typologies

Data Sets : State Quick Facts

Uploaded By: zinggoat
Created at: Friday May 18, 3:08 PM
Data Source: US Census Bureau
Description:
Tags: people census

view as text | edit data set

	People QuickFacts	Population 2005 estimate	Population percent change April 1 2000 to July 1 2005	Population 2000	Population percent change 1990 to 2000	Persons under 5 years old percent 2004	Persons under 18 years old percent 2004	Persons 65 years old and over percent 2004
1	Alabama	4557808	0.03	4447100	0.1	0.07	0.24	0.13
2	Alaska	663661	0.06	626932	0.14	0.08	0.29	0.06
3	Arizona	5939292	0.16	5130632	0.4	0.08	0.27	0.13
4	Arkansas	2779154	0.04	2673400	0.14	0.07	0.25	0.14
5	California	36132147	0.07	33871648	0.14	0.07	0.27	0.11
6	Colorado	4665177	0.08	4301261	0.31	0.07	0.26	0.1
7	Connecticut	3510297	0.03	3405565	0.04	0.06	0.24	0.14
8	Delaware	843524	0.08	783600	0.18	0.07	0.23	0.13
9	Florida	17789864	0.11	15982378	0.24	0.06	0.23	0.17
10	Georgia	9072576	0.11	8186453	0.26	0.08	0.26	0.1
11	Hawaii	1275194	0.05	1211537	0.09	0.07	0.24	0.14
12	Idaho	1429096	0.1	1293953	0.29	0.07	0.27	0.11
13	Illinois	12763371	0.03	12419293	0.09	0.07	0.26	0.12

Choosing a visualization type for State Quick Facts

Analyze a text

Tag Cloud

How are you using your words? This enhanced tag cloud will show you the words popularity in the given set of text.

Learn more

Wordle

Wordle is a toy for generating "word clouds" from text that you provide. The clouds give greater prominence to words that appear more frequently in the source text.

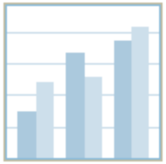
Learn more

Word Tree

See a branching view of how a word or phrase is used in a text. Navigate the text by zooming and clicking.

Learn more

Compare a set of values



Bar Chart

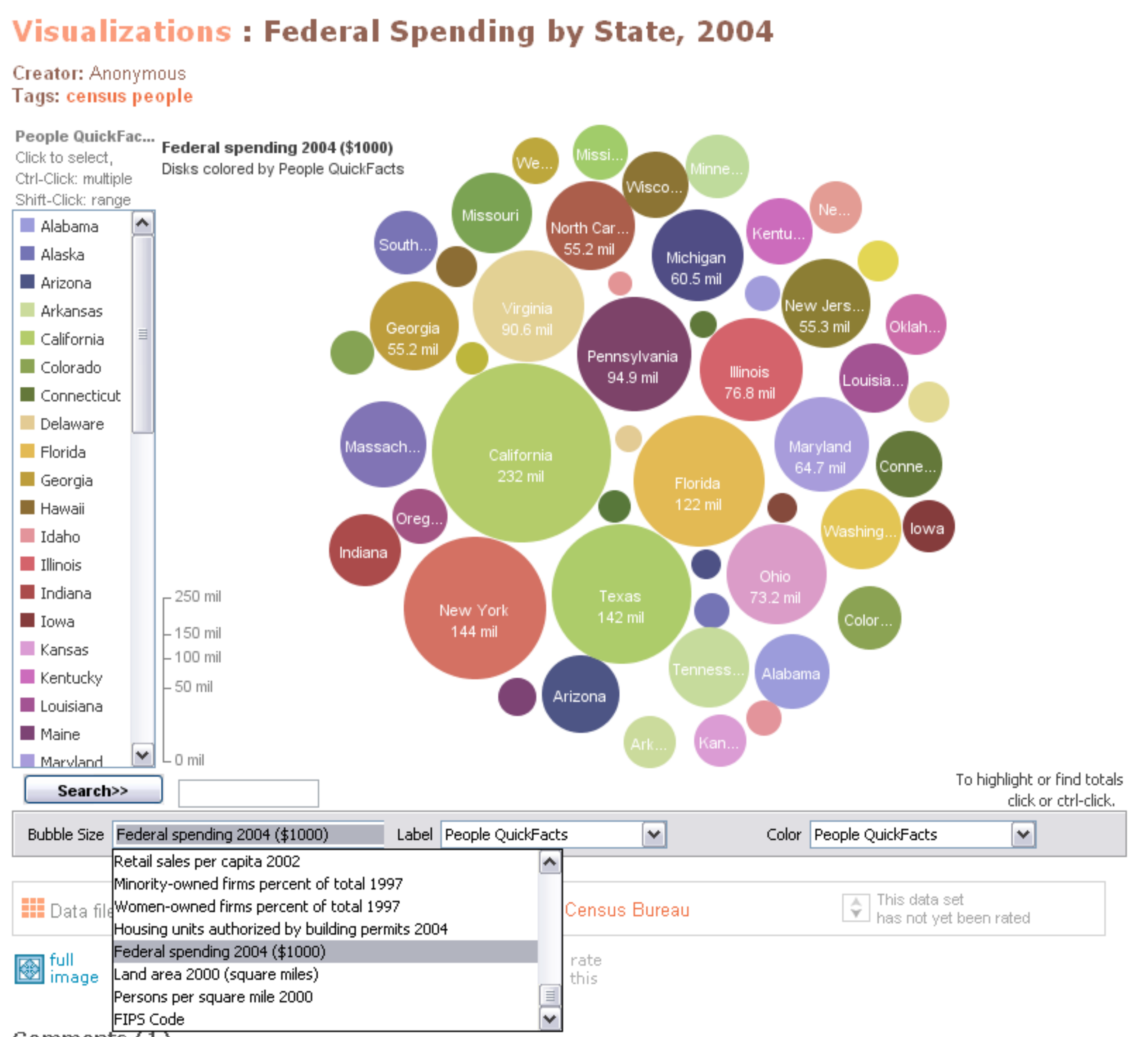
How do the items in your data set stack up? A bar chart is a simple and recognizable way to compare values. You can display several sets of bars for multivariate comparisons.

Learn more

Block Histogram

This versatile chart lets you get a quick sense of how a single set of data is distributed. Each item in the data is an individually identifiable block.

Learn more


Visualizations : Federal Spending by State, 2004
Creator: Anonymous
Tags: census people
People QuickFac...
Click to select,
Ctrl-Click: multiple
Shift-Click: range
Alabama
Alaska
Arizona
Arkansas
California
Colorado
Connecticut
Delaware
Florida
Georgia
Hawaii
Idaho
Illinois
Indiana
Iowa
Kansas
Kentucky
Louisiana
Maine
Maryland
Search>>
Federal spending 2004 ($1000)
Disks colored by People QuickFacts
250 mil
150 mil
100 mil
50 mil
0 mil
We...
Missi...
Minne...
Wisco...
Missouri
North Car...
55.2 mil
Ne...
South...
Michigan
60.5 mil
Kentu...
Virginia
90.6 mil
Georgia
55.2 mil
New Jers...
55.3 mil
Oklah...
Pennsylvania
94.9 mil
Illinois
76.8 mil
Louisia...
Massach...
California
232 mil
Florida
122 mil
Maryland
64.7 mil
Conne...
Oreg...
Washing...
Iowa
Indiana
New York
144 mil
Texas
142 mil
Ohio
73.2 mil
Color...
Tenness...
Alabama
Arizona
Ark...
Kan...
To highlight or find totals
click or ctrl-click.
Bubble Size
Federal spending 2004 ($1000)
Label
People QuickFacts
Color
People QuickFacts
Retail sales per capita 2002
Minority-owned firms percent of total 1997
Women-owned firms percent of total 1997
Housing units authorized by building permits 2004
Federal spending 2004 ($1000)
Land area 2000 (square miles)
Persons per square mile 2000
FIPS Code
Data file
Census Bureau
This data set
has not yet been rated
full
image
rate
this

MAD LIBS®

MY MUSIC LESSON

Every Wednesday, when I get home from school, I have a piano lesson. My teacher is a very strict house (NOUN). Her name is Hillary Clinton (CELEBRITY (FEMALE)). Our piano is a Steinway Concert tree (NOUN) and it has 88 ~~[illegible]~~ cups (PLURAL NOUN). It also has a soft pedal and a/an Smily (ADJECTIVE) pedal. When I have a lesson, I sit down on the piano AlBERTO (NOUN) and play for 16 minuts (PERIOD OF TIME). I do scales to exercise my cats (PLURAL NOUN), and then I usually play a minuet by Johann Sebastian washington (CELEBRITY (LAST NAME)). Teacher says I am a natural Haunted House (NOUN) and have a good musical leg (PART OF THE BODY). Perhaps when I get better I will become a concert vet (PROFESSION) and give a recital at Carnegie hospital (TYPE OF BUILDING).

[M]ost charting packages channel user requests into a **rigid array of chart types**. To atone for this lack of flexibility, they offer a kit of post-creation editing tools to return the image to what the user originally envisioned. **They give the user an impression of having explored data rather than the experience**.

Leland Wilkinson
The Grammar of Graphics, 1999

Chart Typologies

Excel, Many Eyes, Google Charts

Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

Chart Typologies

Excel, Many Eyes, Google Charts

Visual Analysis Grammars

VizQL, ggplot2

Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

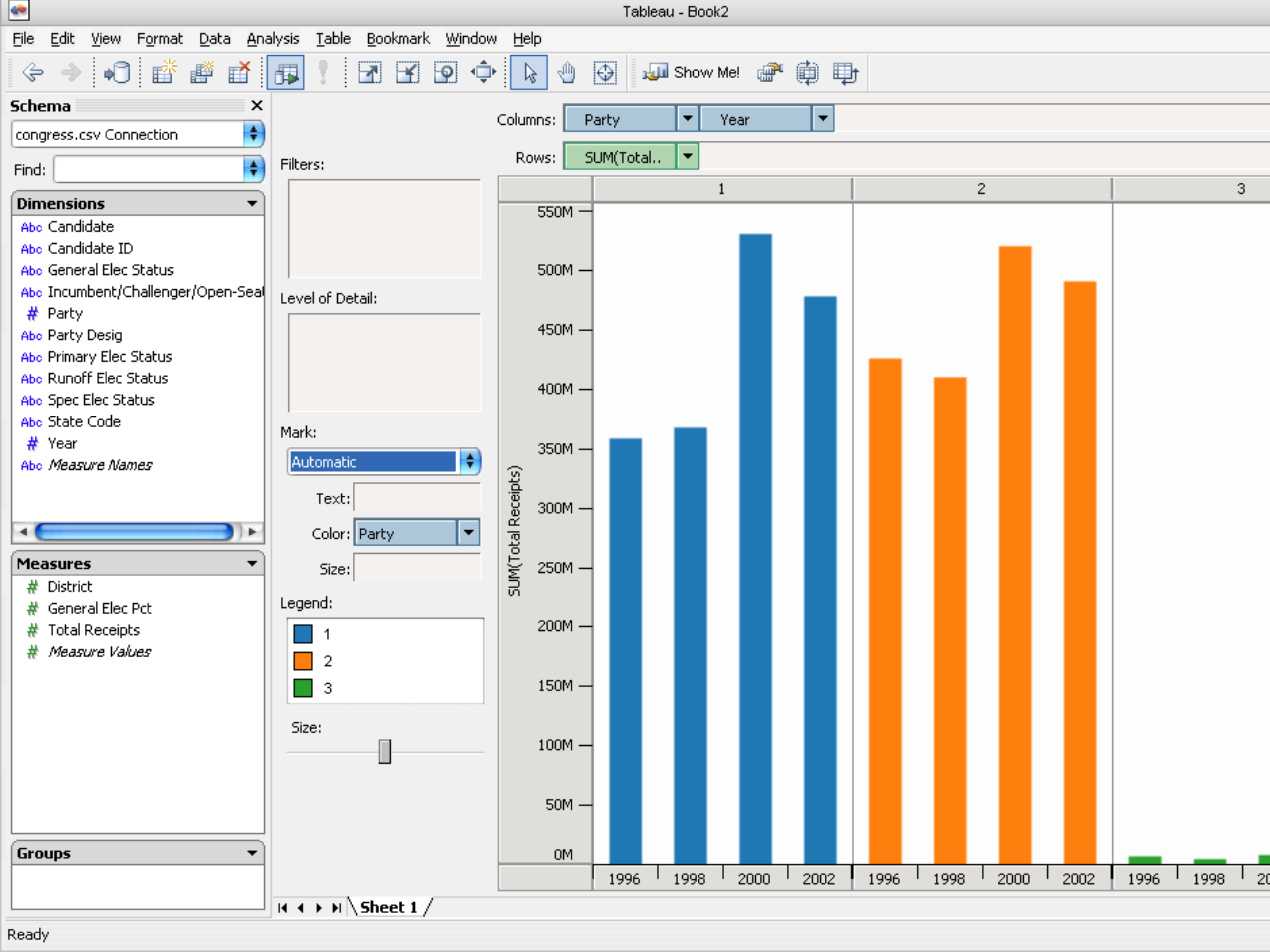


Tableau - Book2
File Edit View Format Data Analysis Table Bookmark Window Help
Show Me!
Schema
congress.csv Connection
Find:
Dimensions
Abc Candidate
Abc Candidate ID
Abc General Elec Status
Abc Incumbent/Challenger/Open-Seat
Party
Abc Party Desig
Abc Primary Elec Status
Abc Runoff Elec Status
Abc Spec Elec Status
Abc State Code
Year
Abc Measure Names
Measures
District
General Elec Pct
Total Receipts
Measure Values
Groups
Filters:
Level of Detail:
Mark:
Automatic
Text:
Color: Party
Size:
Legend:
1
2
3
Size:
Columns: Party Year
Rows: SUM(Total..
1
2
3
550M
500M
450M
400M
350M
300M
250M
200M
150M
100M
50M
0M
SUM(Total Receipts)
1996
1998
2000
2002
1996
1998
2000
2002
1996
1998
Sheet 1
Ready

Statistics and Computing

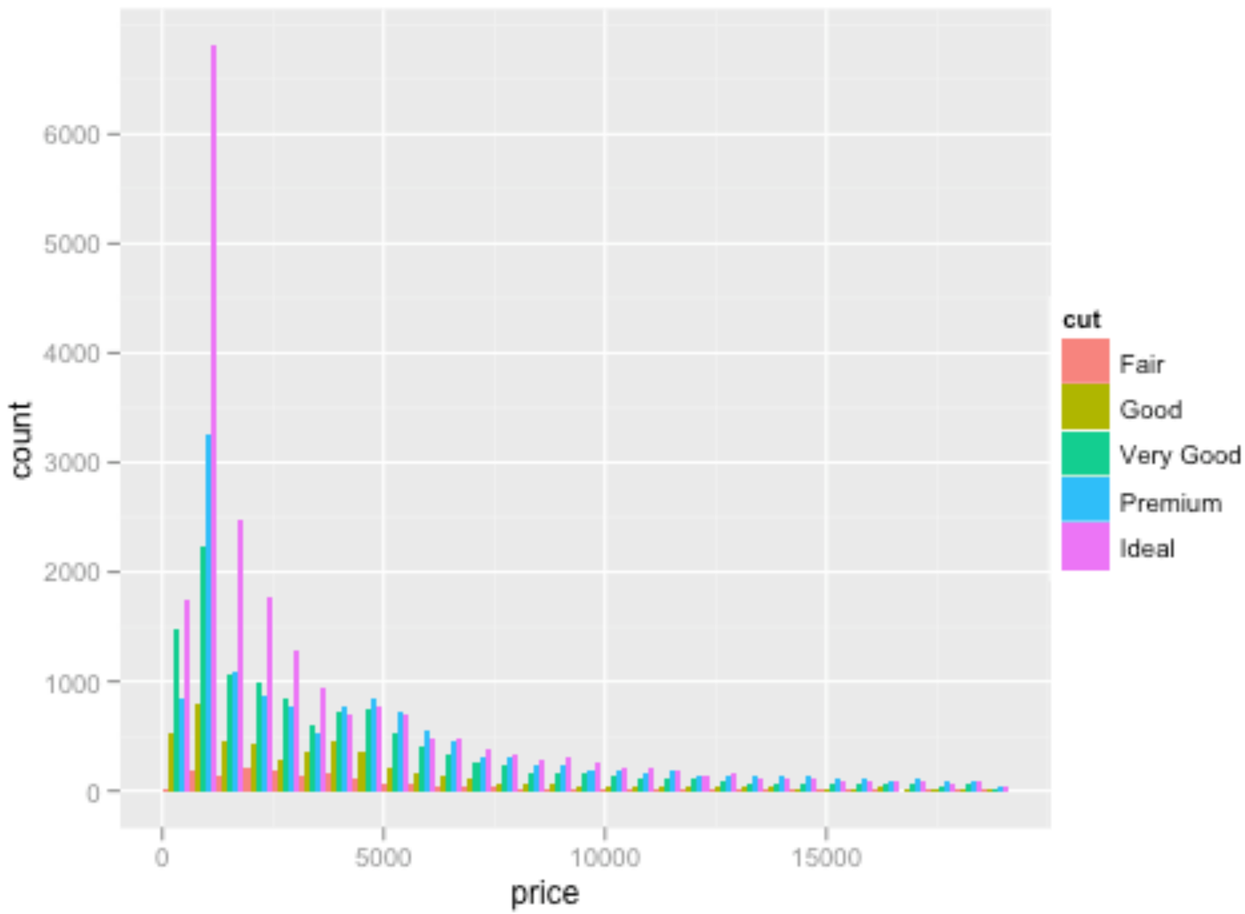
Leland Wilkinson

The Grammar of Graphics

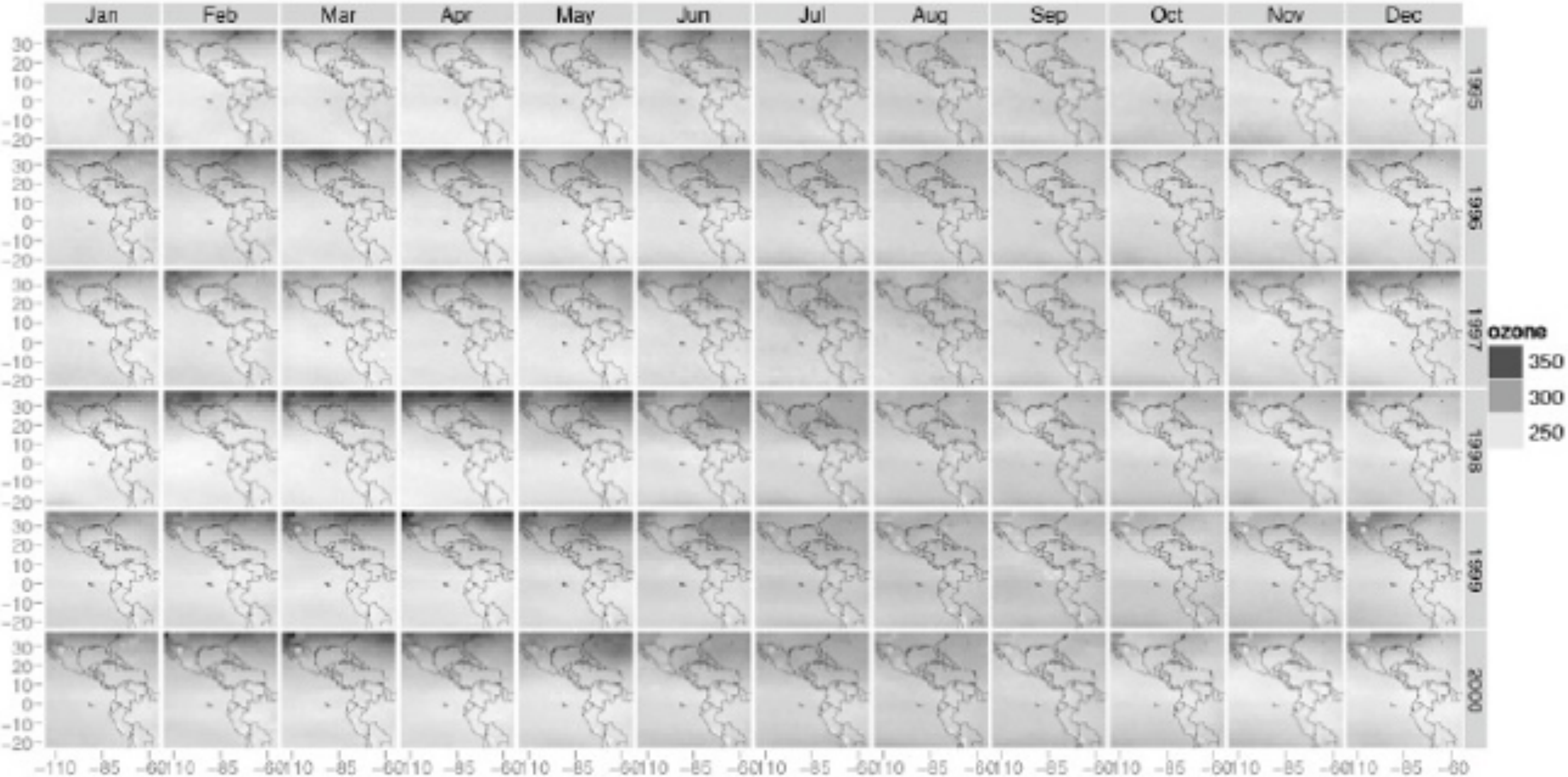
Second Edition

Springer

```
ggplot(diamonds, aes(x=price, fill=cut))
+ geom_bar(position="dodge")
```




```
ggplot(diamonds, aes(x=price, fill=cut))
+ geom_bar(position="dodge")
```




```
qplot(long, lat, data = expo, geom = "tile", fill = ozone,
  facets = year ~ month) +
scale_fill_gradient(low = "white", high = "black") + map
```

Chart Typologies

Excel, Many Eyes, Google Charts

Visual Analysis Grammars

VizQL, ggplot2

Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

Ease-of-Use

Chart Typologies

Excel, Many Eyes, Google Charts

Visual Analysis Grammars

VizQL, ggplot2

Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

Ease-of-Use

Expressiveness

Chart Typologies

Excel, Many Eyes, Google Charts

Visual Analysis Grammars

VizQL, ggplot2

Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

Ease-of-Use

Chart Typologies

Excel, Many Eyes, Google Charts

Visual Analysis Grammars

VizQL, ggplot2

?

Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

Expressiveness

Ease-of-Use

Expressiveness

Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Component Architectures
Prefuse, Flare, Improvise, VTK

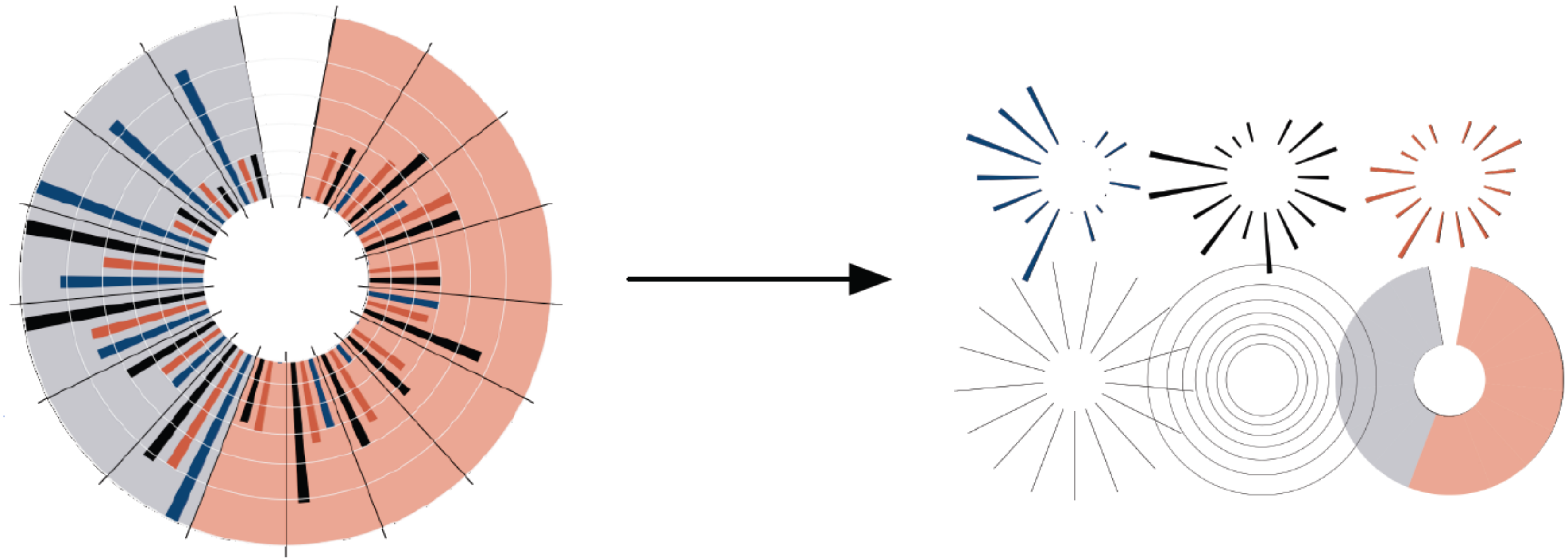
Graphics APIs
Processing, OpenGL, Java2D

Protovis & D3

Today's first task is not to invent wholly new [*graphical*] techniques, though these are needed. Rather we need most vitally to recognize and reorganize the **essential of old techniques**, to **make easy their assembly in new ways**, and to **modify their external appearances to fit the new opportunities**.

J. W. Tukey, M. B. Wilk
Data Analysis & Statistics, 1965

Protovis: A Grammar for Visualization



A graphic is a composition of data-representative marks.

with **Mike Bostock** & **Vadim Ogievetsky**

Visualization Grammar

Visualization Grammar

Data	Input data to visualize

Visualization Grammar

Data	Input data to visualize
Transforms	Grouping, stats, projection, layout

Visualization Grammar

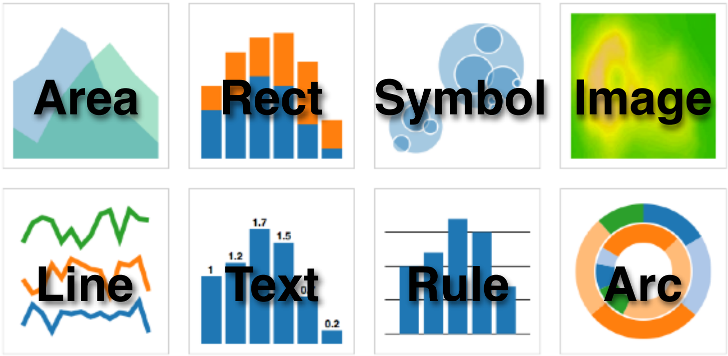
Data	Input data to visualize
Transforms	Grouping, stats, projection, layout
Scales	Map data values to visual values

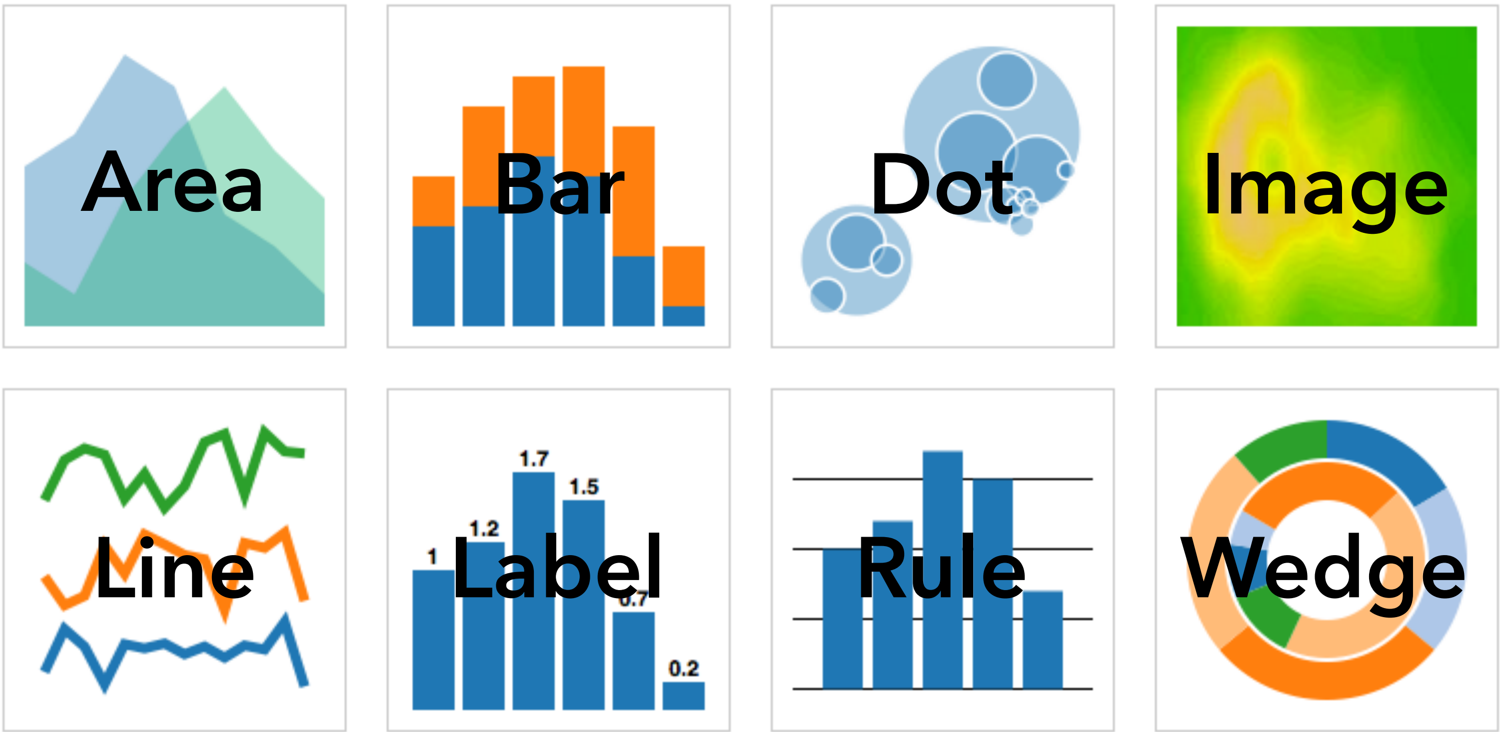
Visualization Grammar

Data	Input data to visualize
Transforms	Grouping, stats, projection, layout
Scales	Map data values to visual values
Guides	Axes & legends visualize scales

Visualization Grammar

Data	Input data to visualize
Transforms	Grouping, stats, projection, layout
Scales	Map data values to visual values
Guides	Axes & legends visualize scales
Marks	Data-representative graphics





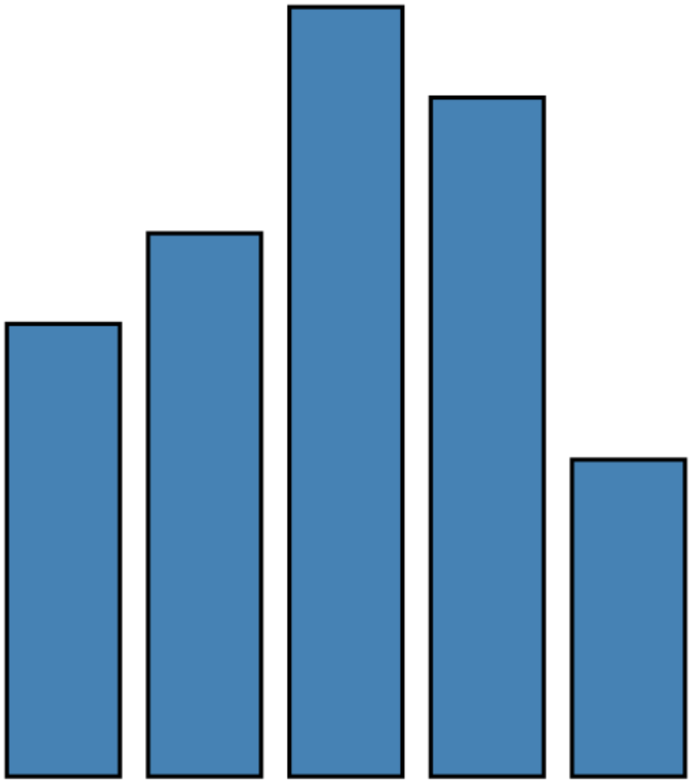
MARKS: Protovis graphical primitives

MARK $\lambda : \boldsymbol{D} \rightarrow \boldsymbol{R}$

data	λ
visible	λ
left	λ
bottom	λ
width	λ
height	λ
fillStyle	λ
strokeStyle	λ
lineWidth	λ
...	λ

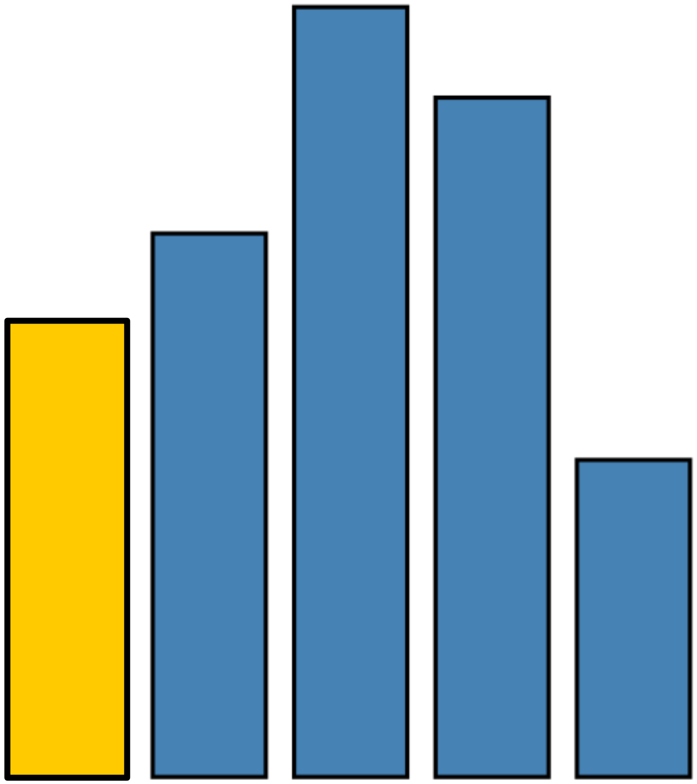
RECT $\lambda : D \rightarrow R$

data	1	1.2	1.7	1.5	0.7
visible	true				
left	λ: index * 25				
bottom	0				
width	20				
height	λ: datum * 80				
fillStyle	blue				
strokeStyle	black				
lineWidth	1.5				
...	...				



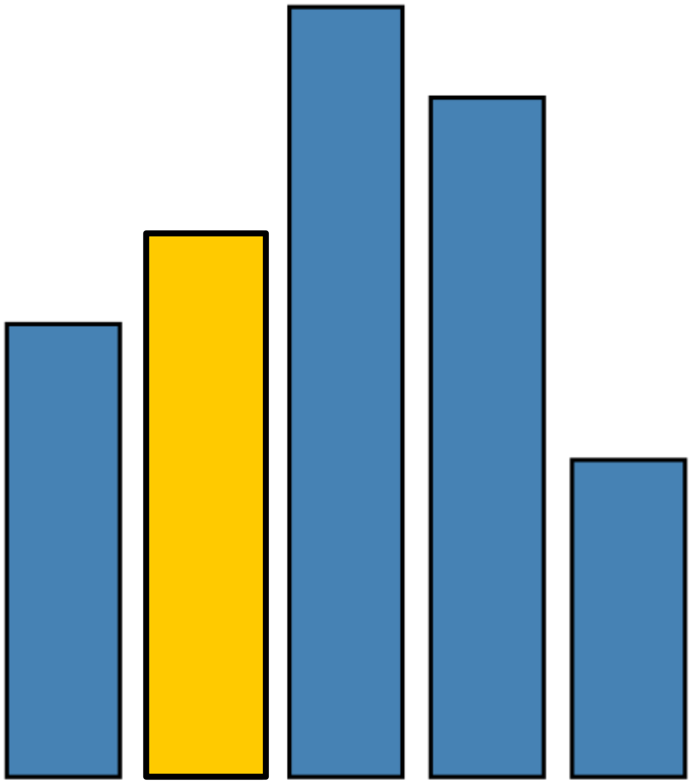
RECT $\lambda : \boldsymbol{D} \rightarrow \boldsymbol{R}$

data	1	1.2	1.7	1.5	0.7
visible	true				
left	0 * 25				
bottom	0				
width	20				
height	1 * 80				
fillStyle	blue				
strokeStyle	black				
lineWidth	1.5				
...	...				



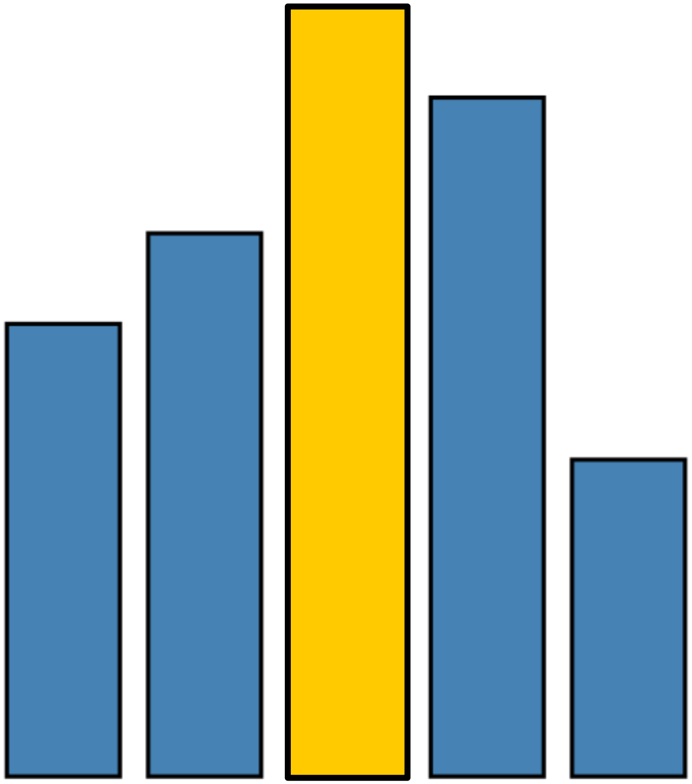
RECT $\lambda : \boldsymbol{D} \rightarrow \boldsymbol{R}$

data	1	1.2	1.7	1.5	0.7
visible	true				
left	1 * 25				
bottom	0				
width	20				
height	1.2 * 80				
fillStyle	blue				
strokeStyle	black				
lineWidth	1.5				
...	...				



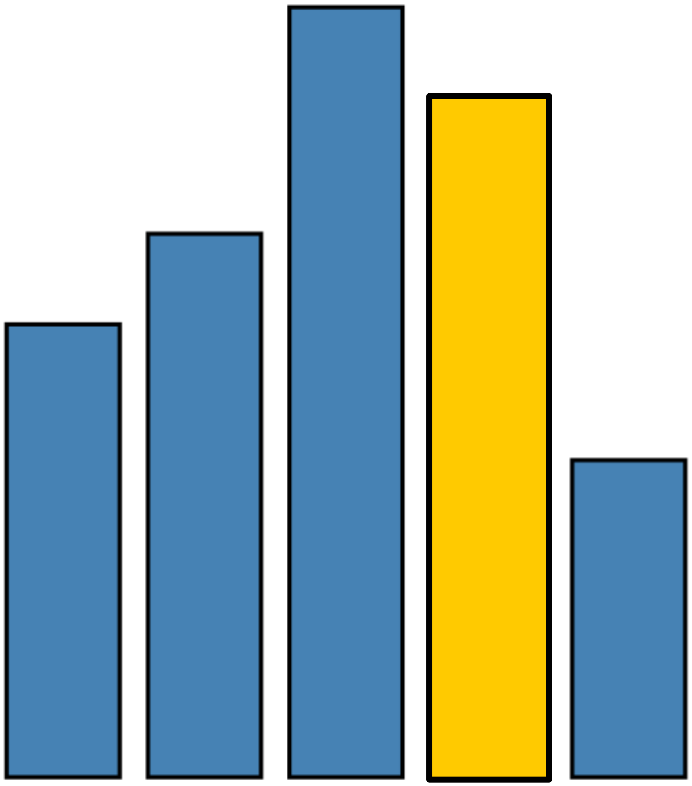
RECT $\lambda : \boldsymbol{D} \rightarrow \boldsymbol{R}$

data	1	1.2	1.7	1.5	0.7
visible	true				
left	2 * 25				
bottom	0				
width	20				
height	1.7 * 80				
fillStyle	blue				
strokeStyle	black				
lineWidth	1.5				
...	...				



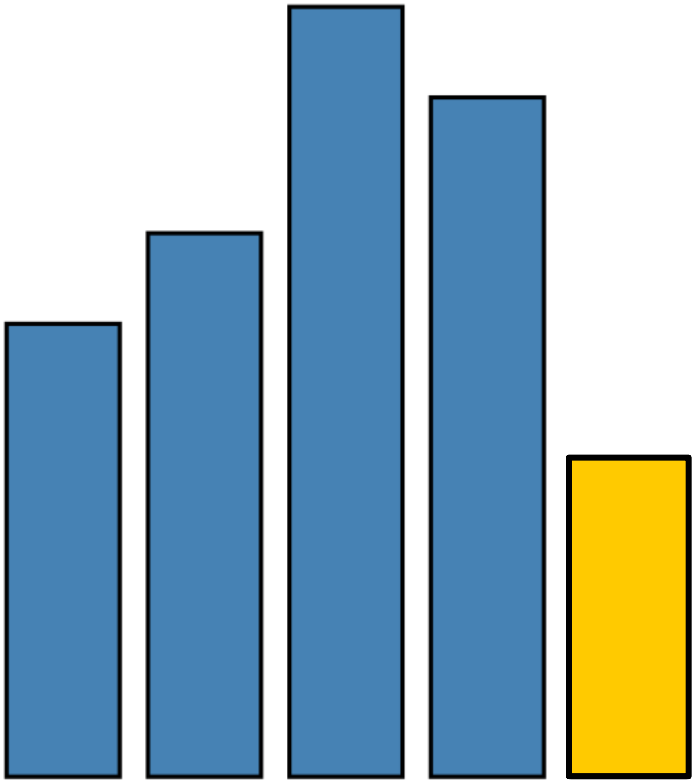
RECT $\lambda : D \rightarrow R$

data	1	1.2	1.7	1.5	0.7
visible	true				
left	3 * 25				
bottom	0				
width	20				
height	1.5 * 80				
fillStyle	blue				
strokeStyle	black				
lineWidth	1.5				
...	...				



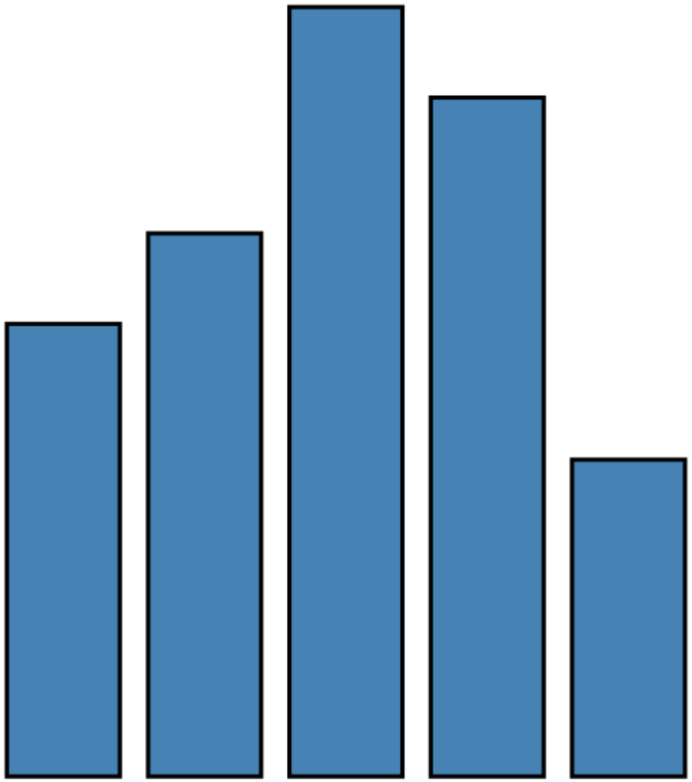
RECT $\lambda : \boldsymbol{D} \to \boldsymbol{R}$

data	1	1.2	1.7	1.5	0.7
visible	true				
left	4 * 25				
bottom	0				
width	20				
height	0.7 * 80				
fillStyle	blue				
strokeStyle	black				
lineWidth	1.5				
...	...				

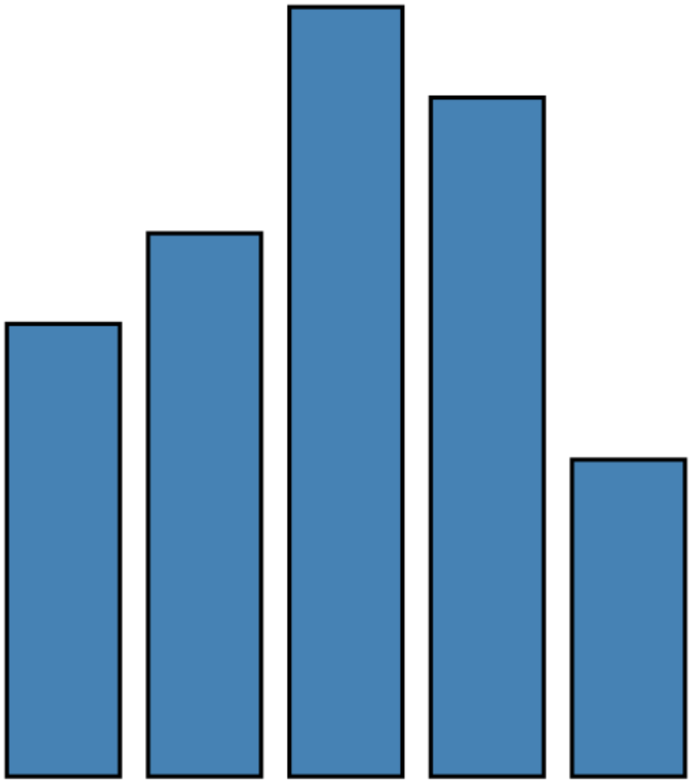


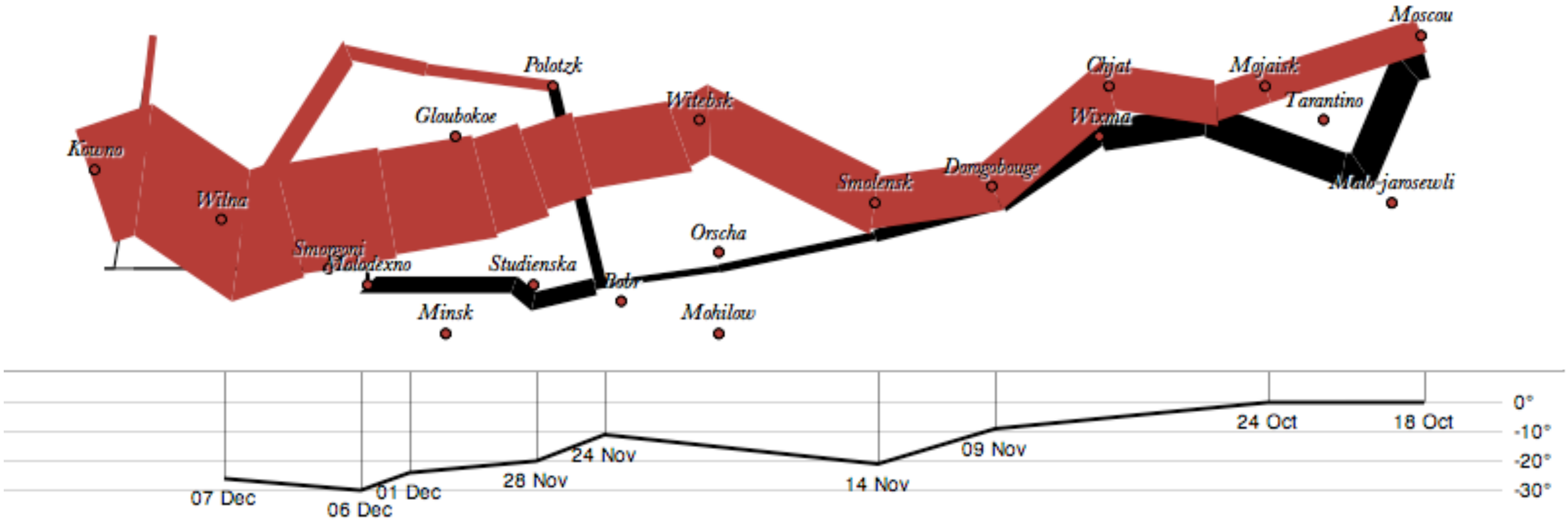
RECT $\lambda : \boldsymbol{D} \rightarrow \boldsymbol{R}$

data	1	1.2	1.7	1.5	0.7
visible	true				
left	λ: index * 25				
bottom	0				
width	20				
height	λ: datum * 80				
fillStyle	blue				
strokeStyle	black				
lineWidth	1.5				
...	...				



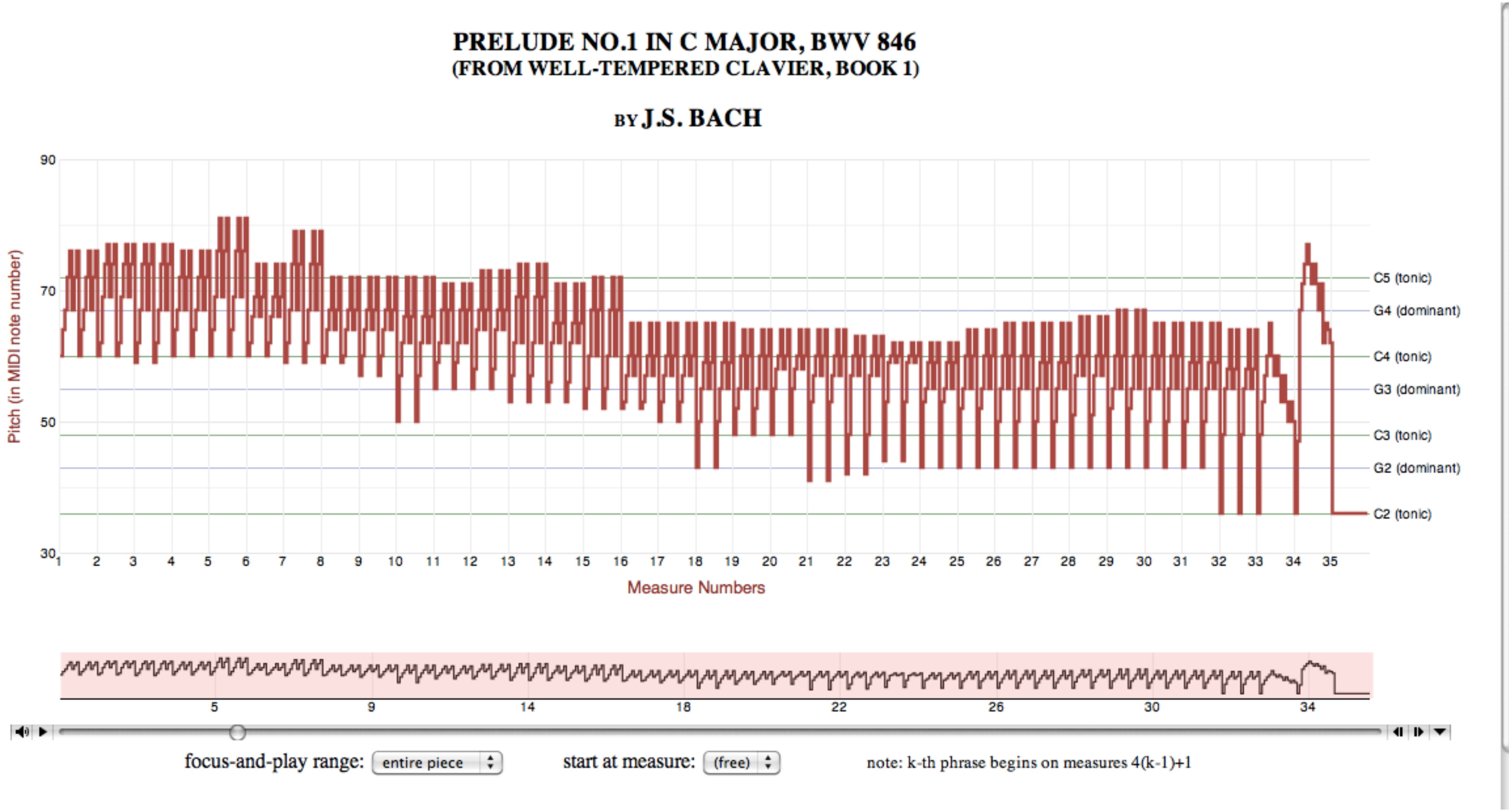
```
var vis = new pv.Panel();
vis.add(pv.Bar)
  .data([1, 1.2, 1.7, 1.5, 0.7])
  .visible(true)
  .left((d) => this.index * 25);
  .bottom(0)
  .width(20)
  .height((d) => d * 80)
  .fillStyle("blue")
  .strokeStyle("black")
  .lineWidth(1.5);
vis.render();
```



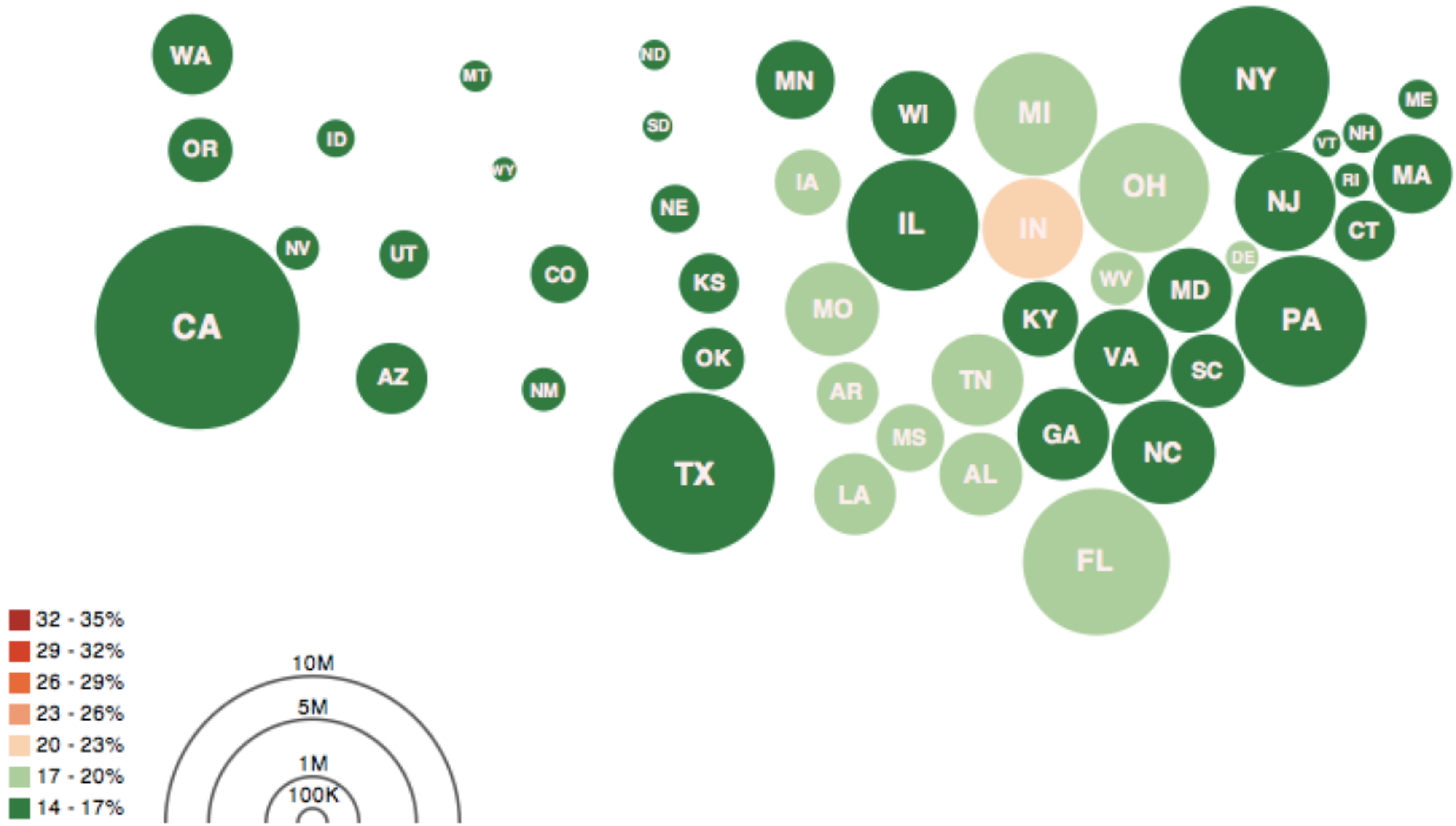



```
var army = pv.nest(napoleon.army, "dir", "group");
var vis = new pv.Panel();

var lines = vis.add(pv.Panel).data(army);
lines.add(pv.Line)
  .data(() => army[this.idx])
  .left(lon).top(lat).size((d) => d.size/8000)
  .strokeStyle(() => color[army[paneIndex][0].dir]);

vis.add(pv.Label).data(napoleon.cities)
  .left(lon).top(lat)
  .text((d) => d.city).font("italic 10px Georgia")
  .textAlign("center").textBaseline("middle");
```

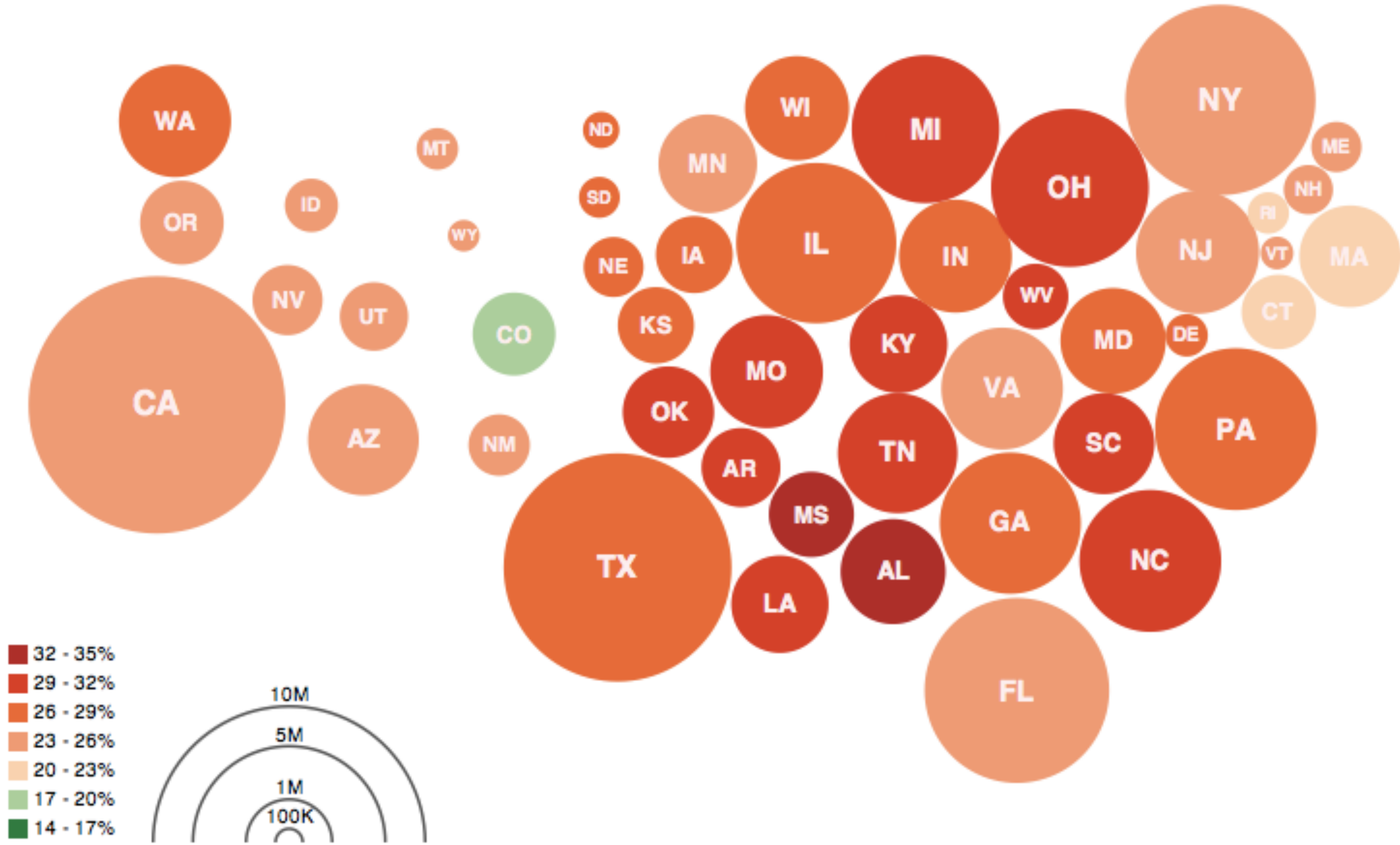
```
vis.add(pv.Rule).data([0,-10,-20,-30])
  .top((d) => 300 - 2*d - 0.5).left(200).right(150)
  .lineWidth(1).strokeStyle("#ccc")
  .anchor("right").add(pv.Label)
   .font("italic 10px Georgia")
   .text((d) => d+"°").textBaseline("center");

vis.add(pv.Line).data(napoleon.temp)
  .left(lon).top(tmp) .strokeStyle("#0")
 .add(pv.Label)
  .top((d) => 5 + tmp(d))
  .text((d) => d.temp+"° "+d.date.substr(0,6))
  .textBaseline("top").font("italic 10px Georgia");
```



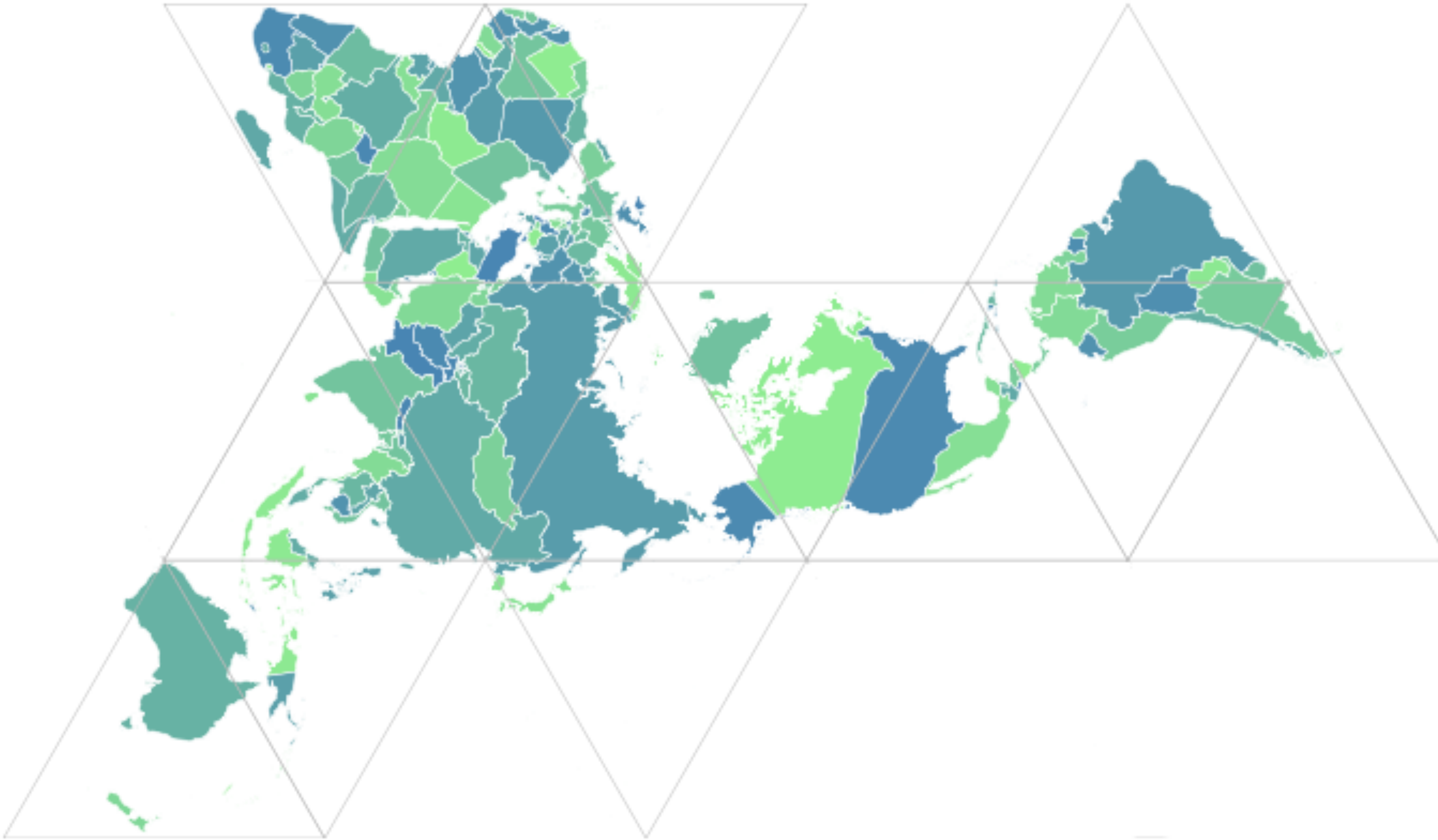
Bach's Prelude #1 in C Major | Jieun Oh



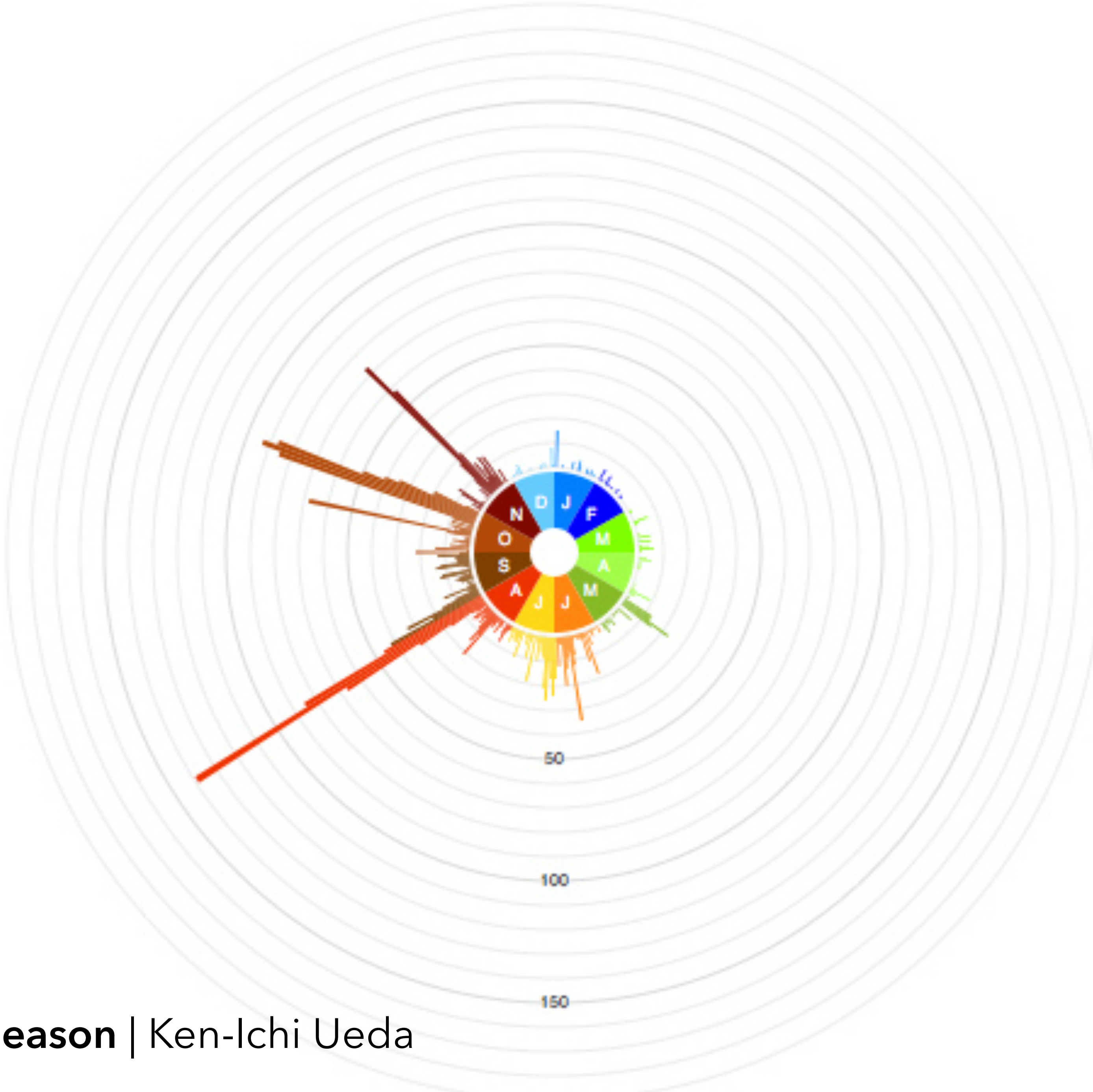
Obesity Map | Vadim Ogievetsky



Obesity Map | Vadim Ogievetsky

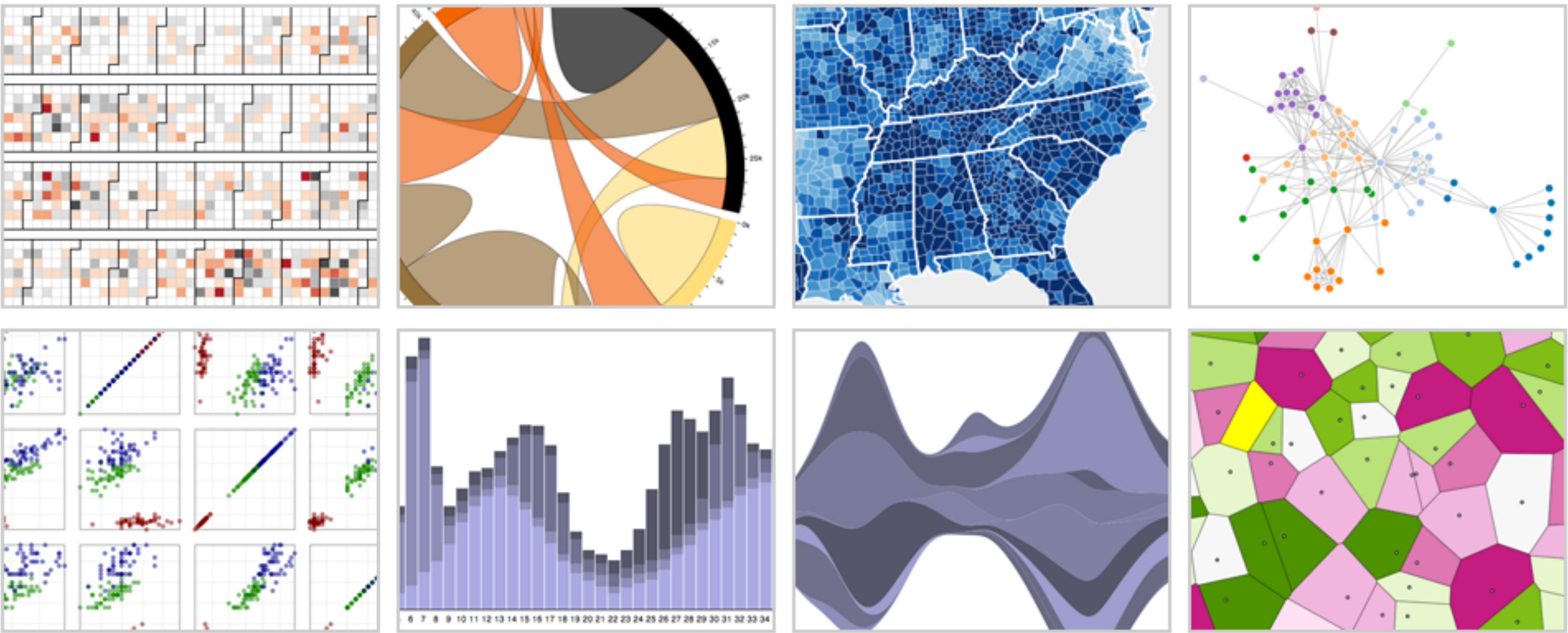


Dymaxion Maps | Vadim Ogievetsky



FlickrSeason | Ken-Ichi Ueda

d3.js Data-Driven Documents



with **Mike Bostock** & Vadim Ogievetsky

Protovis

Specialized mark types

+ Streamlined design
- Limits expressiveness
- More overhead (slower)
- Harder to debug
- Self-contained model

Specify a scene (nouns)

+ Quick for static vis
- Delayed evaluation
- Animation, interaction are more cumbersome

Protovis

Specialized mark types

\+ Streamlined design
\- Limits expressiveness
\- More overhead (slower)
\- Harder to debug
\- Self-contained model

Specify a scene (nouns)

\+ Quick for static vis
\- Delayed evaluation
\- Animation, interaction
are more cumbersome

D3

Bind data to DOM

\- Exposes SVG/CSS/…
\+ Exposes SVG/CSS/…
\+ Less overhead (faster)
\+ Debug in browser
\+ Use with other tools

Transform a scene (verbs)

\- More complex model
\+ Immediate evaluation
\+ Dynamic data, anim,
and interaction natural

D3 Selections

The core abstraction in D3 is a ***selection***.

D3 Selections

The core abstraction in D3 is a ***selection***.

```
// Add and configure an SVG element
var svg = d3.append(“svg”)      // add new SVG to page body
    .attr(“width”, 500)         // set SVG width to 500px
    .attr(“height”, 300);       // set SVG height to 300px
```

D3 Selections

The core abstraction in D3 is a ***selection***.

```
// Add and configure an SVG element
var svg = d3.append(“svg”)          // add new SVG to page body
    .attr(“width”, 500)             // set SVG width to 500px
    .attr(“height”, 300);           // set SVG height to 300px

// Select & update existing rectangles contained in the SVG element
svg.selectAll(“rect”)               // select all SVG rectangles
    .attr(“width”, 100)             // set rect widths to 100px
    .style(“fill”, “steelblue”);    // set rect fill colors
```

Data Binding

Selections can ***bind*** **data and DOM elements**.

var values = [{…}, {…}, {…}, …]; // input data as JS objects

Data Binding

Selections can ***bind*** **data and DOM elements**.

```
var values = [ {…}, {…}, {…}, … ]; // input data as JS objects

// Select SVG rectangles and bind them to data values.
var bars = svg.selectAll("rect.bars").data(values);
```

Data Binding

Selections can ***bind*** **data and DOM elements**.

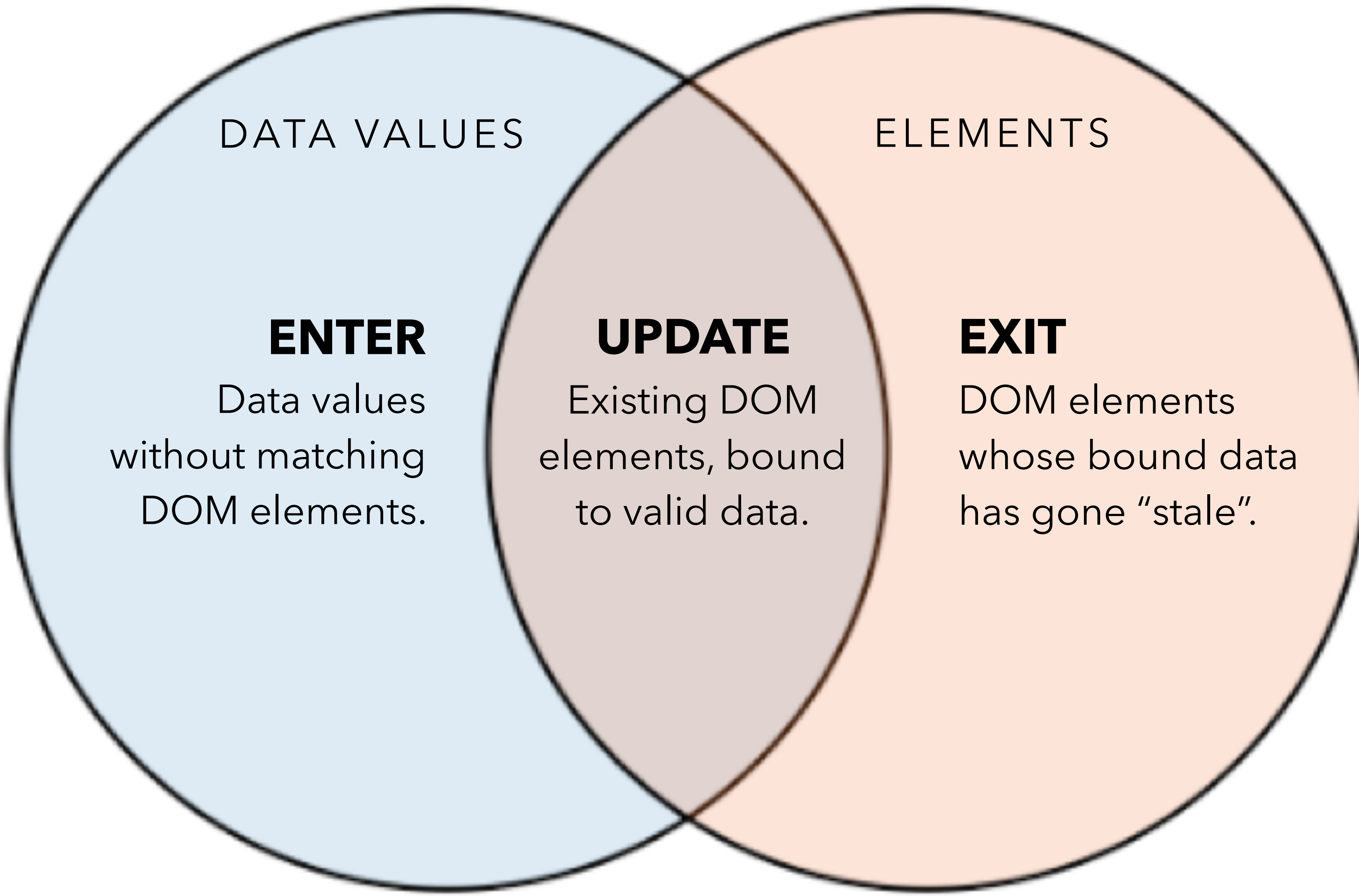
```
var values = [ {…}, {…}, {…}, … ]; // input data as JS objects

// Select SVG rectangles and bind them to data values.
var bars = svg.selectAll(“rect.bars”).data(values);

// What if the DOM elements don’t exist yet? The enter set represents data
// values that do not yet have matching DOM elements.
bars.enter().append(“rect”).attr(“class”, “bars”);
```

Data Binding

Selections can ***bind* data and DOM elements**.

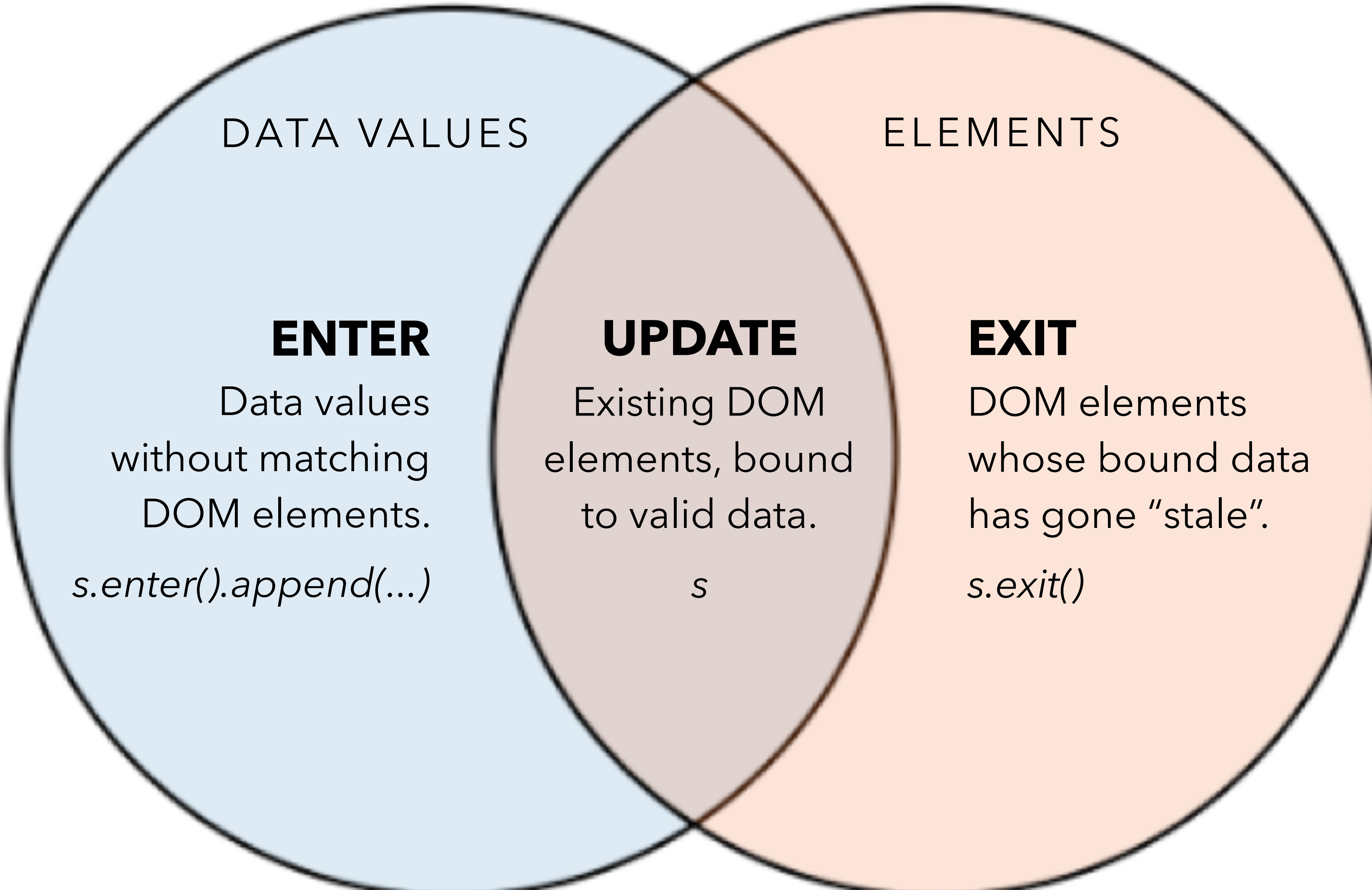
```
var values = [ {…}, {…}, {…}, … ]; // input data as JS objects

// Select SVG rectangles and bind them to data values.
var bars = svg.selectAll("rect.bars").data(values);

// What if the DOM elements don't exist yet? The enter set represents data
// values that do not yet have matching DOM elements.
bars.enter().append("rect").attr("class", "bars");

// What if data values are removed? The exit set is a selection of existing
// DOM elements who no longer have matching data values.
bars.exit().remove();
```

The Data Join



The Data Join

var s = d3.selectAll(...).data(...)



D3 Modules

Data Parsing / Formatting (JSON, CSV, …)
Shape Helpers (arcs, curves, areas, symbols, …)
Scale Transforms (linear, log, ordinal, …)
Color Spaces (RGB, HSL, LAB, …)
Animated Transitions (tweening, easing, …)
Geographic Mapping (projections, clipping, …)
Layout Algorithms (stack, pie, force, trees, …)
Interactive Behaviors (brush, zoom, drag, …)

Many of these correspond to future lecture topics!

Ease-of-Use

Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D

Expressiveness

Administrivia

A2: Exploratory Data Analysis

Use visualization software to form & answer que s

First steps:

Step 1: Pick domain & data

Step 2: Pose questions

Step 3: Profile the da

Iterate as needed

Cre at

Inte with c

Refine ur qu ons

Autho ort

Screensh ots of most insightful views *(10+)*

Include titles and captions for each view

Due by 11:59pm

Friday, Apr 13

DONE

D3.js Tutorial

Date: **Thursday, April 19**

Time: **4:30pm to 6:30pm**

Location: **Sieg 134**

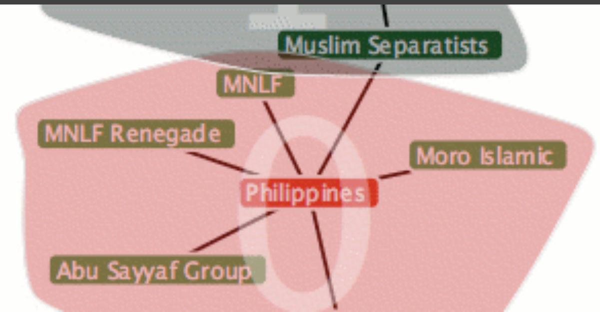
D3.js is a popular JavaScript visualization library, valuable for A3 and your Final Project…

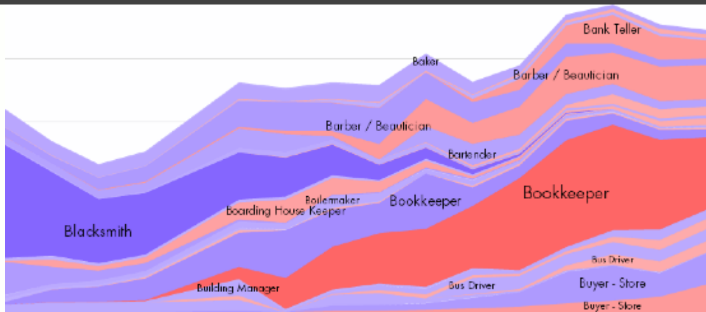
A3: Interactive Prototype

Create an interactive visualization. Choose a driving question for a dataset and develop an appropriate visualization + interaction techniques, then deploy your visualization on the web.

Due by *11:59pm* on **Monday, April 30**.

Work in project teams of 3-4 people.



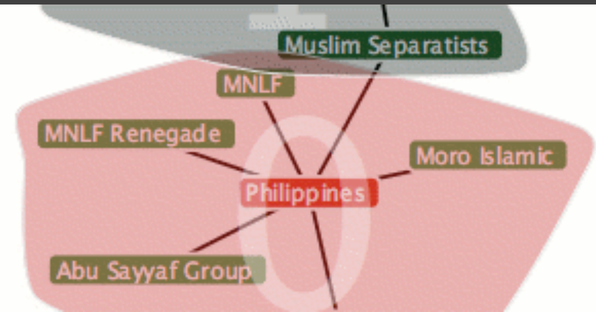


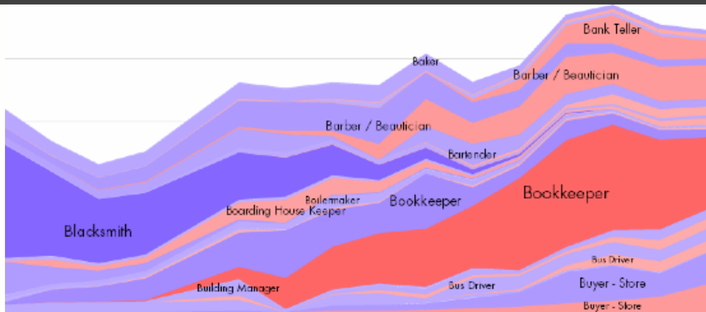
Requirements

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

Web-based. D3 is encouraged, but not required. Deploy your visualization using GitHub pages.

Write-up. Provide design rationale on your web page.





A3 Project Team

Form a **team of 3-4** for A3 *ASAP*.

(Start thinking about your Final Project, too!)

A3 is open-ended, but you can use it to start exploring FP topics if you like.

Submit signup form by **Friday 4/20, 11:59pm**.

If you do not have team mates, you should:

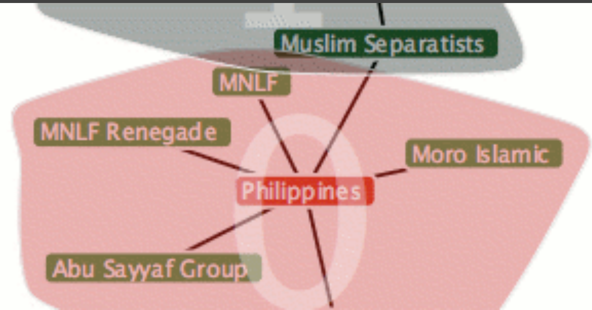
- Use the facilities on Canvas
- Stay after class/tutorial to meet potential partners

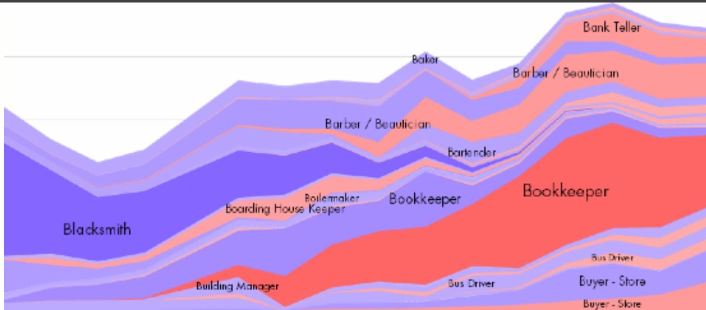
Interactive Prototype Tips

Start now. It will take longer than you think.

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

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





A Visualization Tool Stack

Chart Typologies

Excel, Many Eyes, Google Charts

Visual Analysis Grammars

VizQL, ggplot2

Visualization Grammars

Protovis, D3.js

Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

Chart Typologies
Excel, Many Eyes, Google Charts

Charting Tools

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Declarative Languages

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D

Programming Toolkits

Chart Typologies
Excel, Many Eyes, Google Charts

Charting Tools

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Declarative Languages

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D

Programming Toolkits

What is a Declarative Language?

What is a Declarative Language?

Programming by describing *what*, not *how*

What is a Declarative Language?

Programming by describing *what*, not *how*

Separate **specification** (*what you want*) from **execution** (*how it should be computed*)

What is a Declarative Language?

Programming by describing *what*, not *how*

Separate **specification** (*what you want*) from **execution** (*how it should be computed*)

In contrast to **imperative programming**, where you must give explicit steps.

What is a Declarative Language?

Programming by describing *what*, not *how*

Separate **specification** (*what you want*) from **execution** (*how it should be computed*)

In contrast to **imperative programming**, where you must give explicit steps.

```
d3.selectAll("rect")
  .data(my_data)
 .enter().append("rect")
  .attr("x", function(d) { return xscale(d.foo); })
  .attr("y", function(d) { return yscale(d.bar); })
```

TODAY'S PAPER | VIDEO | MOST POPULAR | TIMES TOPICS | MOST RECENT — Subscribe to The Times | Welcome, jmheer

The New York Times

Tuesday, October 26, 2010 — Last Update: 3:50 PM ET

Search | ING DIRECT | Subscribe to Hom

— 2010 Midterm Elections —

Tea Party Vow to Deter Voter Fraud Is Called Scare Tactic

By IAN URBINA 2:19 PM ET

Voting rights group say that Tea Party members' plan to question voters' eligibility at the polls is intended to suppress minority and poor voters.

Post a Comment | Read (355)

Glaxo Pays $750 Million Fine for Tainted Products

By GARDINER HARRIS and DUFF

Joshua Kristal for The New York Times

Painting at 99, With No Compromises

By ROBIN FINN

An exhibition celebrating Will Barnet's centennial year traces his evolution as a modern American artist.

OPINION »

OP-ED CONTRIBUTOR

Humans to Asteroids: Watch Out!

How to keep near-Earth objects from hitting us.

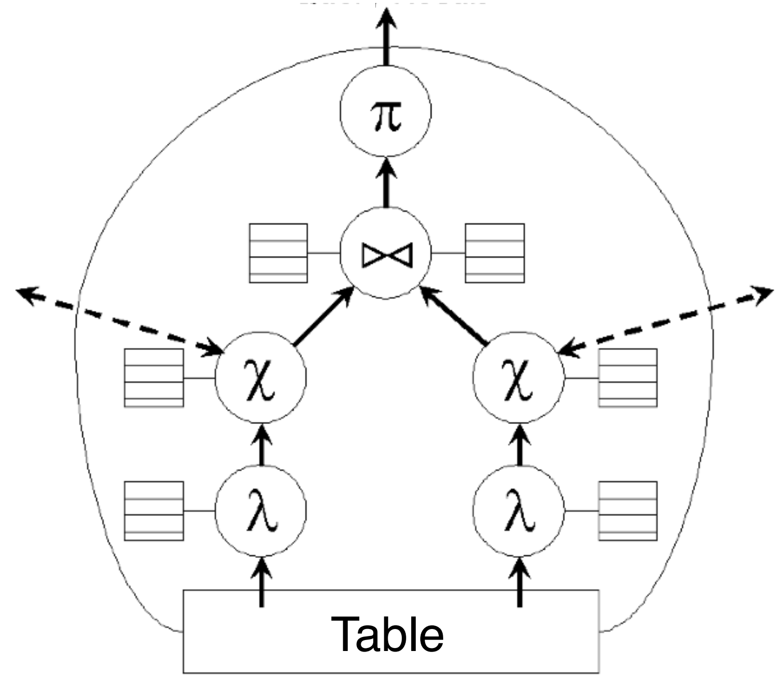
- Brooks: No Second Thoughts | Comments (200)
- Herbert: The Corrosion of America
- Cohen: Turkey Steps Out
- Editorial: Mortgage Mess
- Bloggingheads: Jon Stewart's Power

MARKETS » At 3:56 PM ET

S.&P. 500 | Dow | Nasdaq

```
<!DOCTYPE html PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
"http://www.w3.org/TR/html4/loose.dtd">
<!--[if IE]><![endif]-->
▼<html>
 ▶<head>…</head>
 ▼<body id="home" style="visibility: visible; ">
   <script src="http://connect.facebook.net/en_US/all.js"></scrip
   <div id="fb-root"></div>
   <a name="top"></a>
  ▼<div id="shell">
    ▶<ul id="memberTools">…</ul>
     <!-- ADXINFO classification="text_ad" campaign="nyt2010-circ-
    ▶<div class="tabsContainer">…</div>
     <!-- close .tabsContainer -->
    ▶<div id="page" class="tabContent active">…</div>
     <!--close page -->
   </div>
   <!--close shell -->
 ▶<script type="text/javascript" language="JavaScript">…</script
   <img src="/adx/bin/clientside/
   1b1a1755Q2F,.tWdC,KiQ2BCQ5C6iSM.KCYQ2FMadYYQ24xN!Q2B!xQ24WN4aN
   <script src="http://graphics8.nytimes.com/js/test/wto/wt_capi.
   charset="utf-"></script>
   <span id="wto_script"></span>
 ▶<script type="text/javascript"></script>
   <img src="http://graphics8.nytimes.com/ads/blank.gif">
   <script type="text/javascript" src="http://graphics8.nytimes.c
```

HTML / CSS




```sql
SELECT customer_id, customer_name,
    COUNT(order_id) as total
FROM customers
INNER JOIN orders ON
    customers.customer_id
    = orders.customer_id
GROUP BY customer_id, customer_nam
HAVING COUNT(order_id) > 5
ORDER BY COUNT(order_id) DESC
```

SQL

Why Declarative Languages?

Better visualization? *Smart defaults.*

Reuse. *Write-once, then re-apply.*

Performance. *Optimization, scalability.*

Portability. *Multiple devices, renderers, inputs.*

Programmatic generation.
Write programs which output visualizations.
Automated search & recommendation.

Chart Typologies

Excel, Many Eyes, Google Charts

Charting Tools

Visual Analysis Grammars

VizQL, ggplot2

Visualization Grammars

Protovis, D3.js

Declarative Languages

Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

Programming Toolkits

Chart Typologies

Excel, Many Eyes, Google Charts

Charting Tools

Visual Analysis Grammars

VizQL, ggplot2, ***Vega-Lite***

Declarative Languages

Visualization Grammars

Protovis, D3.js, ***Vega***

Component Architectures

Prefuse, Flare, Improvise, VTK

Programming Toolkits

Graphics APIs

Processing, OpenGL, Java2D

Chart Typologies ?! Charting Tools

Excel, Many Eyes, Google Charts

Visual Analysis Grammars

VizQL, ggplot2, ***Vega-Lite***

Declarative Languages

Visualization Grammars

Protovis, D3.js, ***Vega***

Component Architectures Programming Toolkits

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

Visual Analysis Grammars

VizQL, ggplot2, ***Vega-Lite***

Visualization Grammars

Protovis, D3.js, ***Vega***

Declarative Languages

Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

Programming Toolkits

Interactive Data Exploration

Tableau, ***Lyra, Voyager***

Graphical Interfaces

Visual Analysis Grammars

VizQL, ggplot2, ***Vega-Lite***

Visualization Grammars

Protovis, D3.js, ***Vega***

Declarative Languages

Component Architectures

Prefuse, Flare, Improvise, VTK

Programming Toolkits

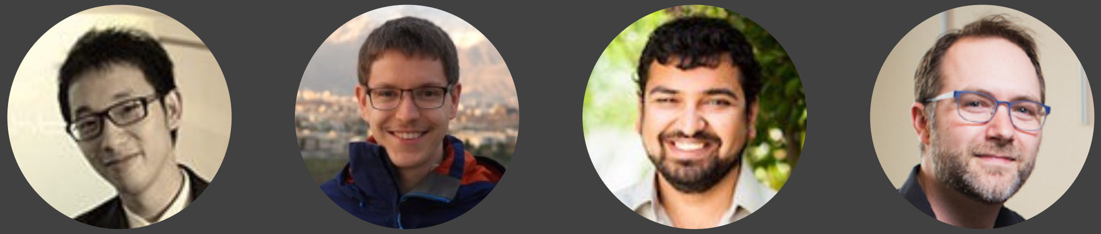
Graphics APIs

Processing, OpenGL, Java2D

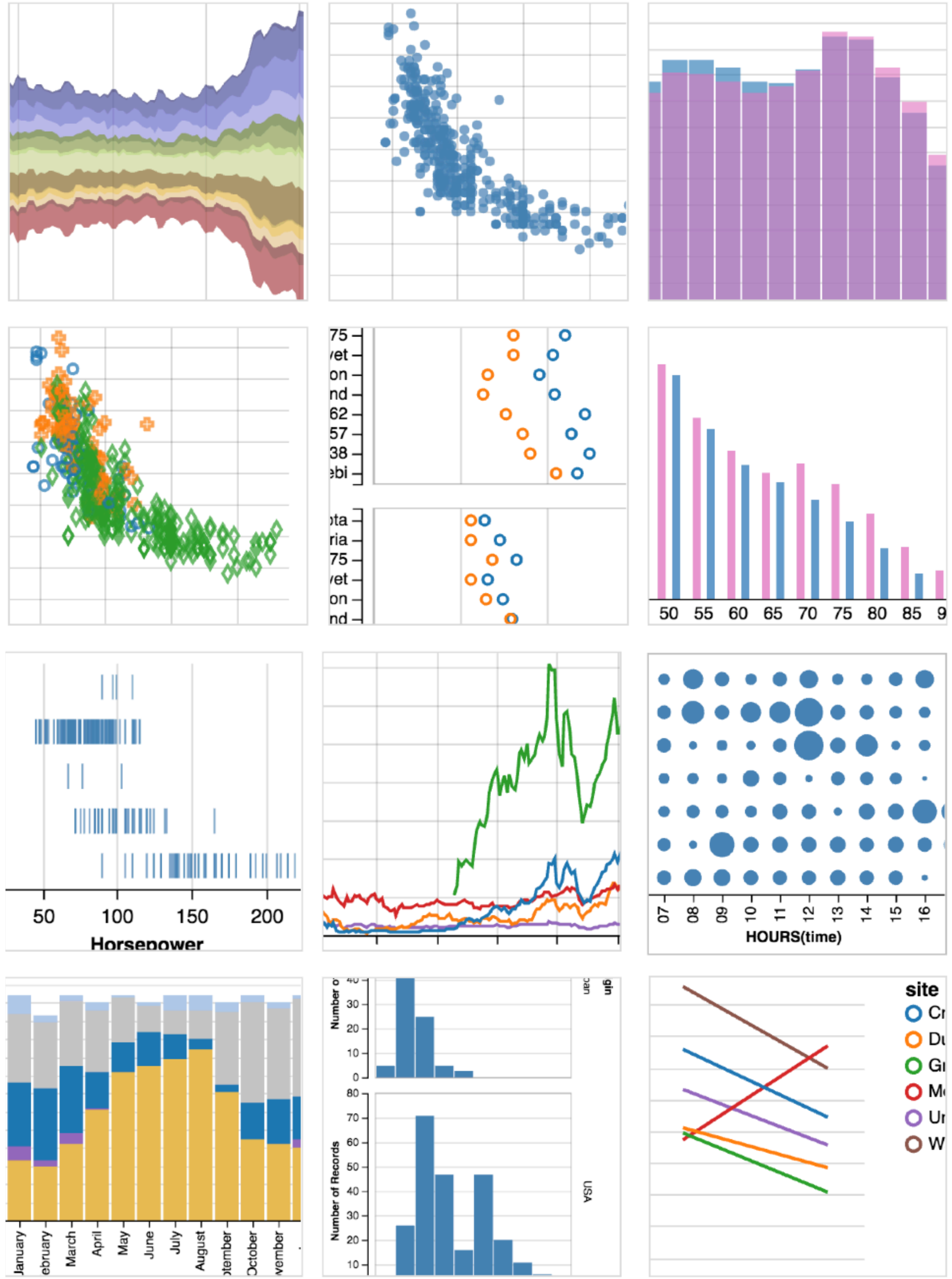
VEGA-LITE

A Grammar of Interactive Graphics

Kanit "Ham" Wongsuphasawat @kanitw
Dominik Moritz @domoritz
Arvind Satyanarayan @arvindsatya1
Jeffrey Heer @jeffrey_heer



Interactive Data Lab @uwdata
University of Washington



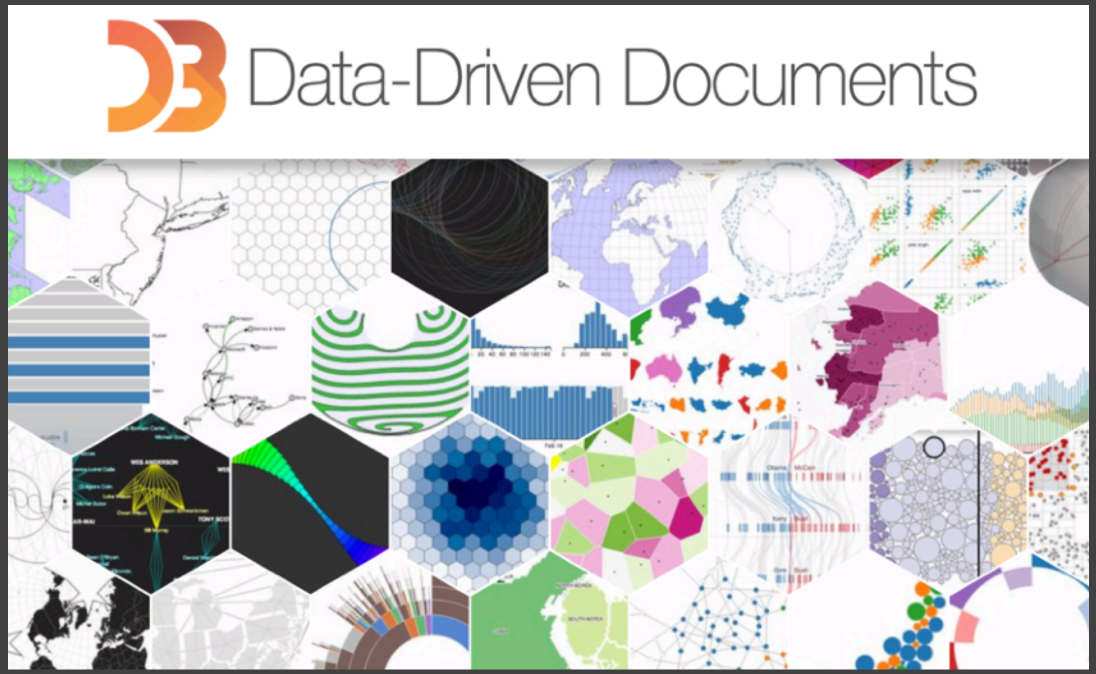
prefuse

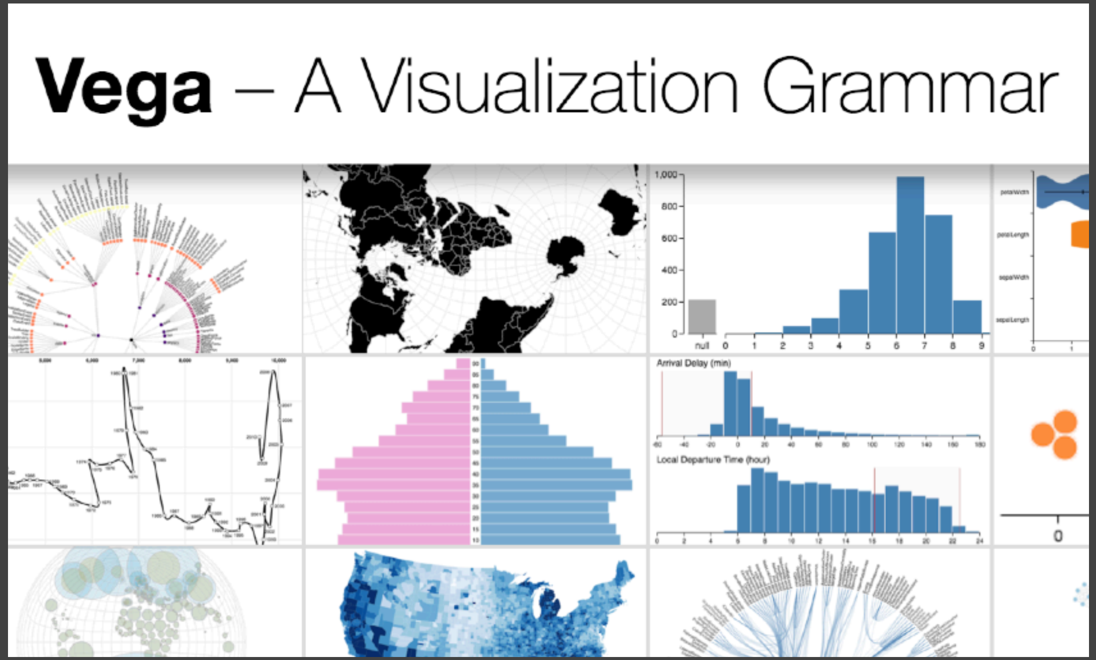
Protovis

vega

D3 Data-Driven Documents

Grammar of Graphics *for Customized Designs*

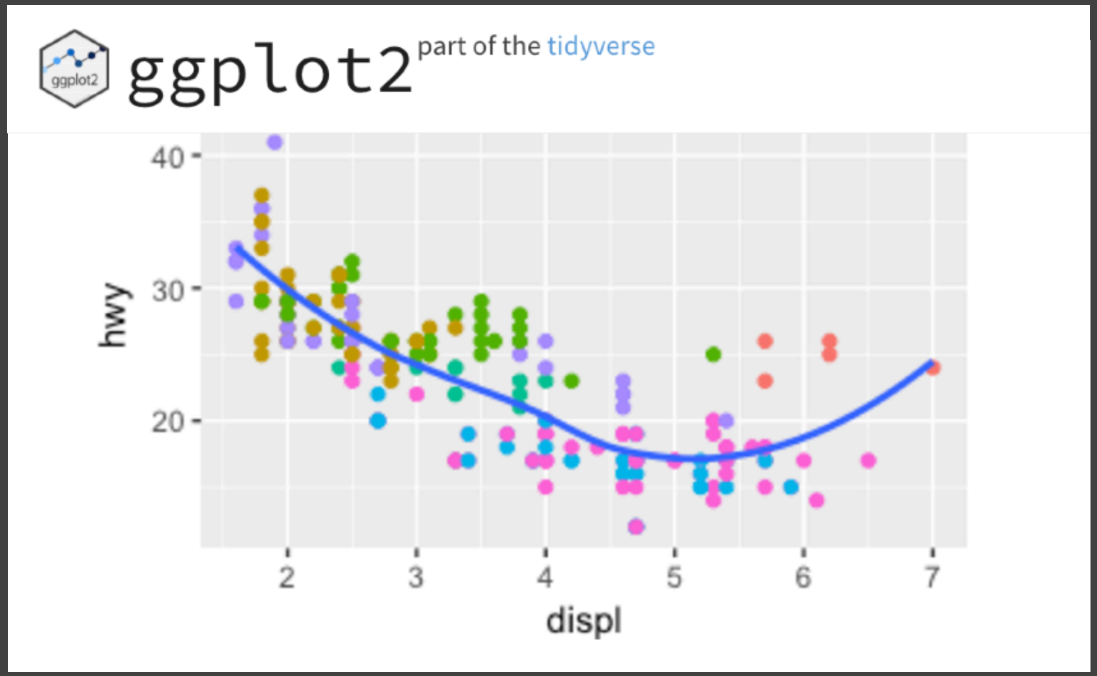


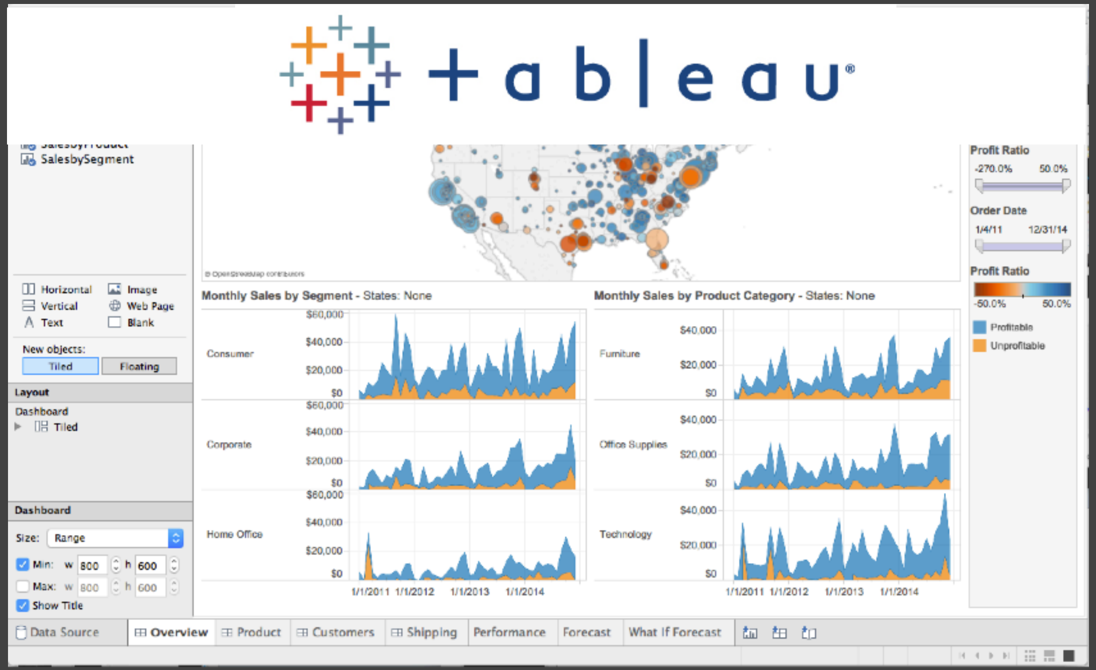


Offer **fine-grained control** for composing interactive graphics.

But require **verbose** specifications and technical expertise.

Grammar of Graphics *for Exploration*



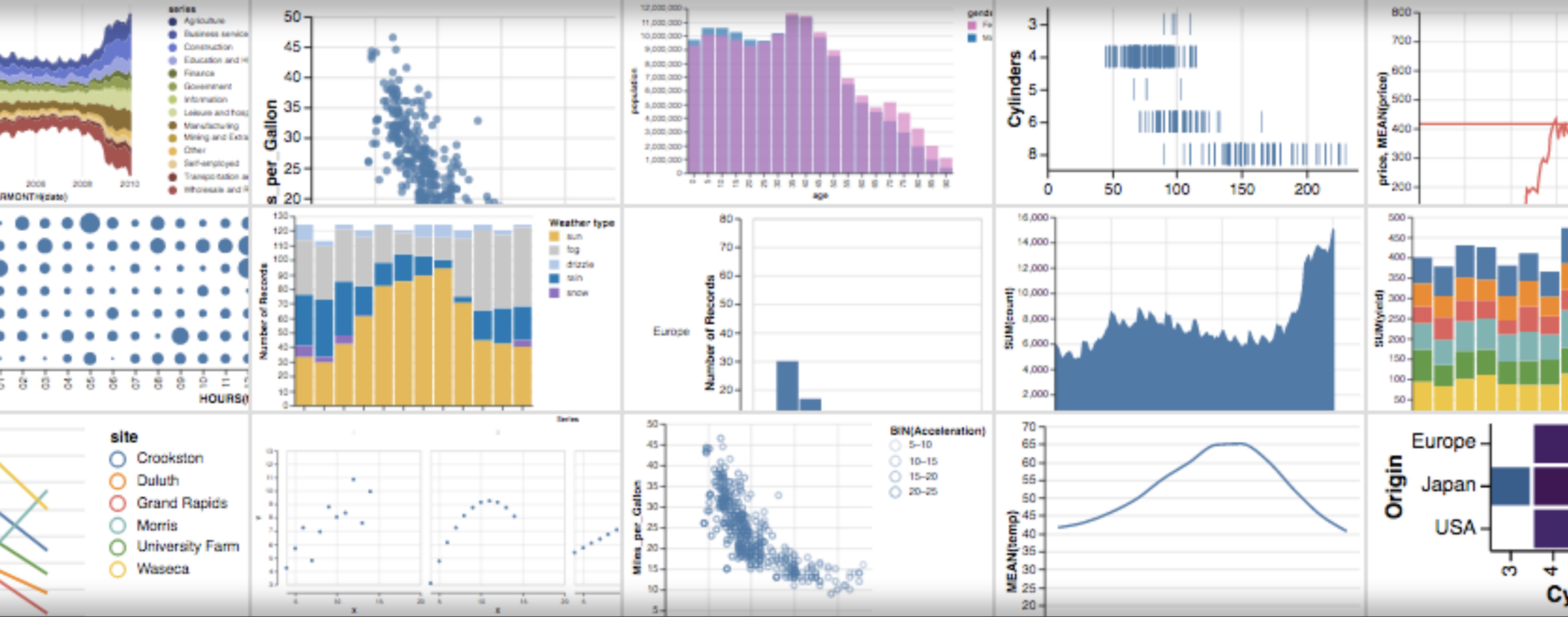


Facilitate **rapid exploration**
with **concise** specifications
by omitting low-level details.

Infer **sensible defaults** and
allow customization
by overriding defaults.

But **limited** support for **interactions.**

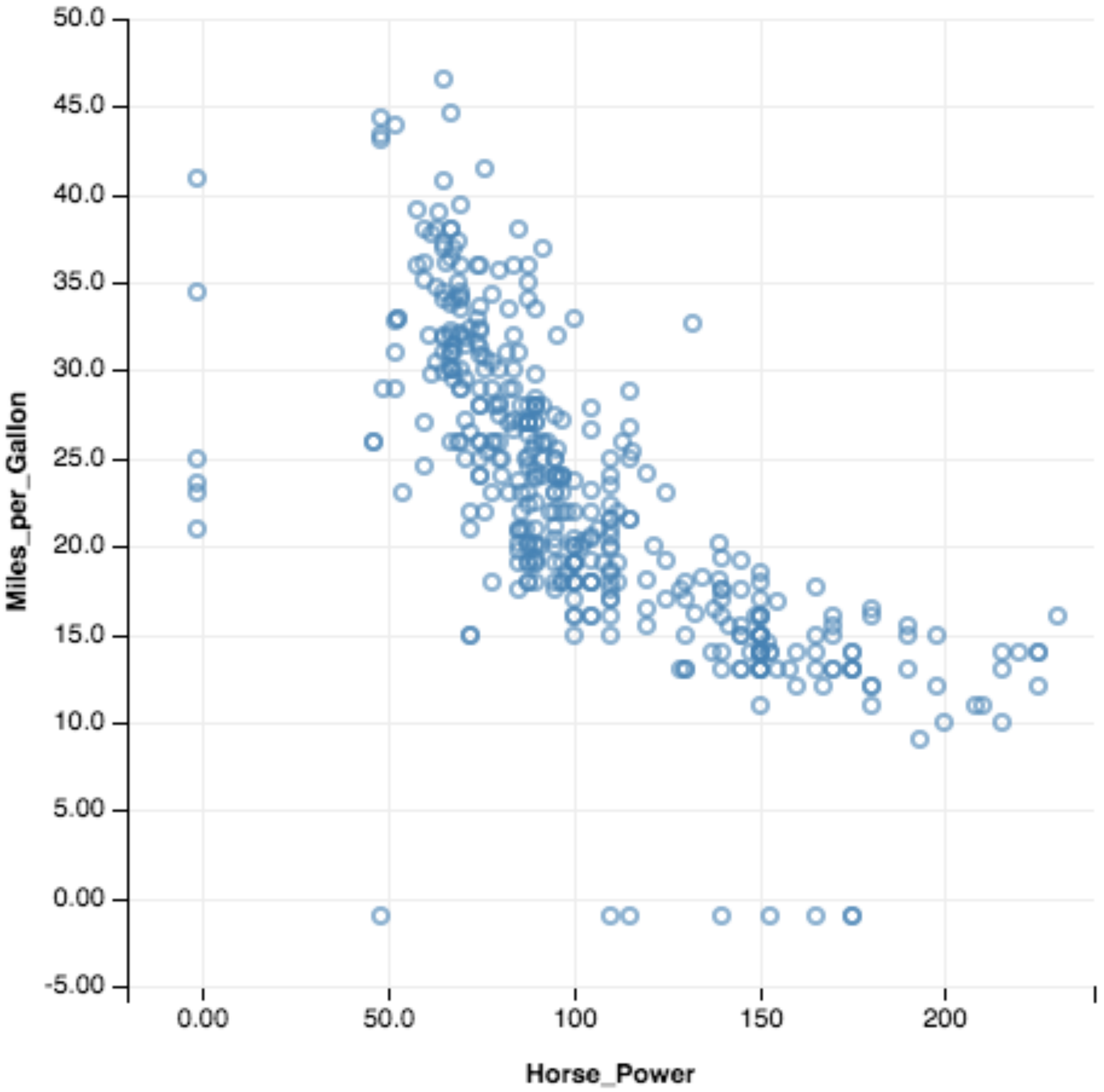
How might we author *interactive* **graphics** in the **midst of analysis**?



Vega-Lite: A Grammar of Interactive Graphics

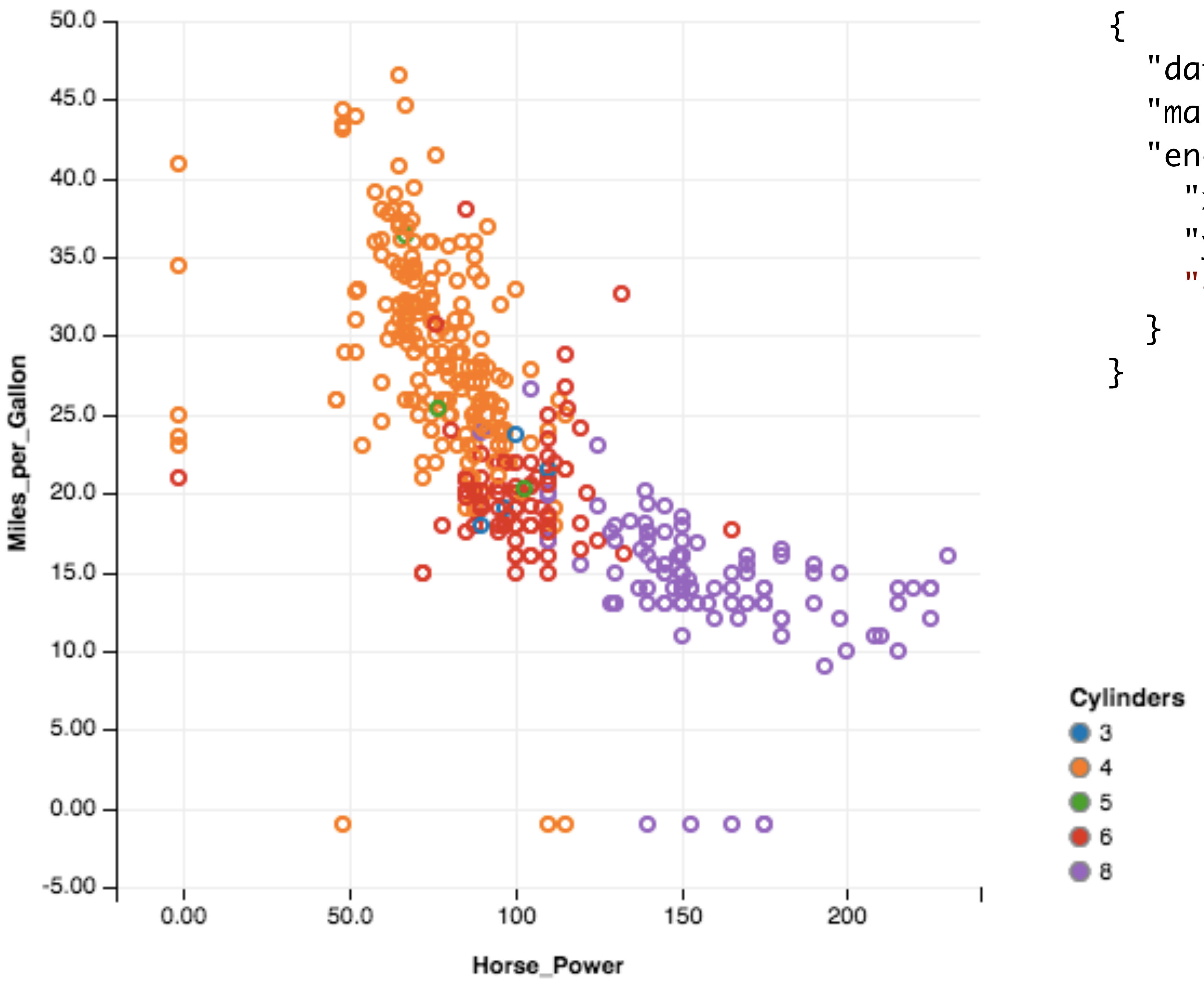
A. Satyanarayan, D. Moritz, K. Wongsuphasawat & J. Heer. *TVCG 2017*

Vega-Lite: Scatter Plot



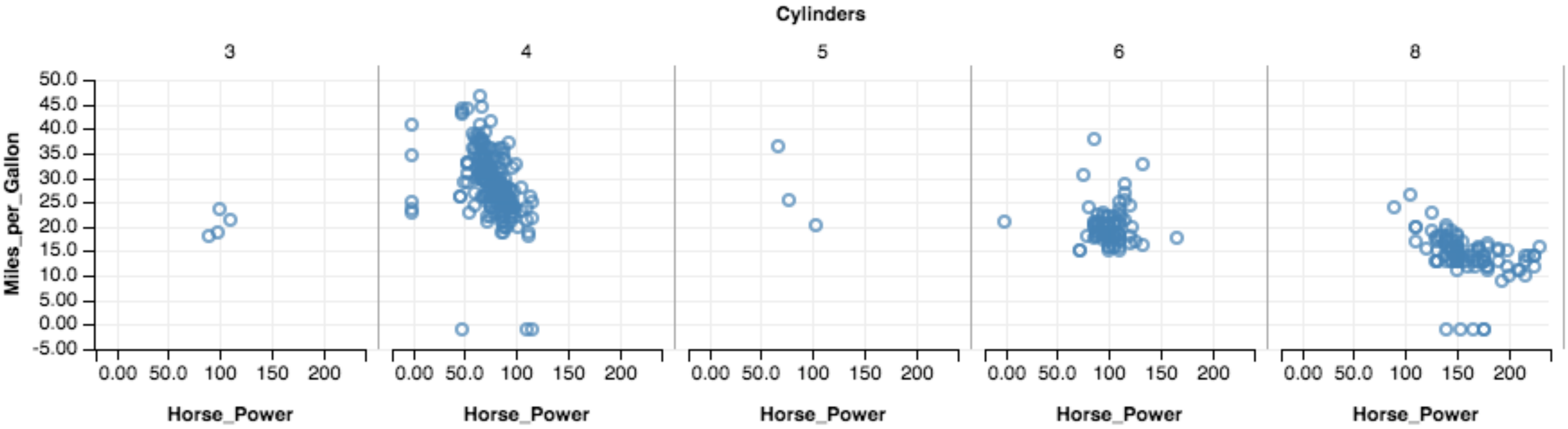

```
{
  "data": {"url": "data/cars.json"},
  "mark": "point",
  "encoding": {
    "x": {"field":"Horse_Power", "type":"Q"},
    "y": {"field":"Miles_per_Gallon", "type":"Q"}
  }
}
```

Vega-Lite: Scatter Plot



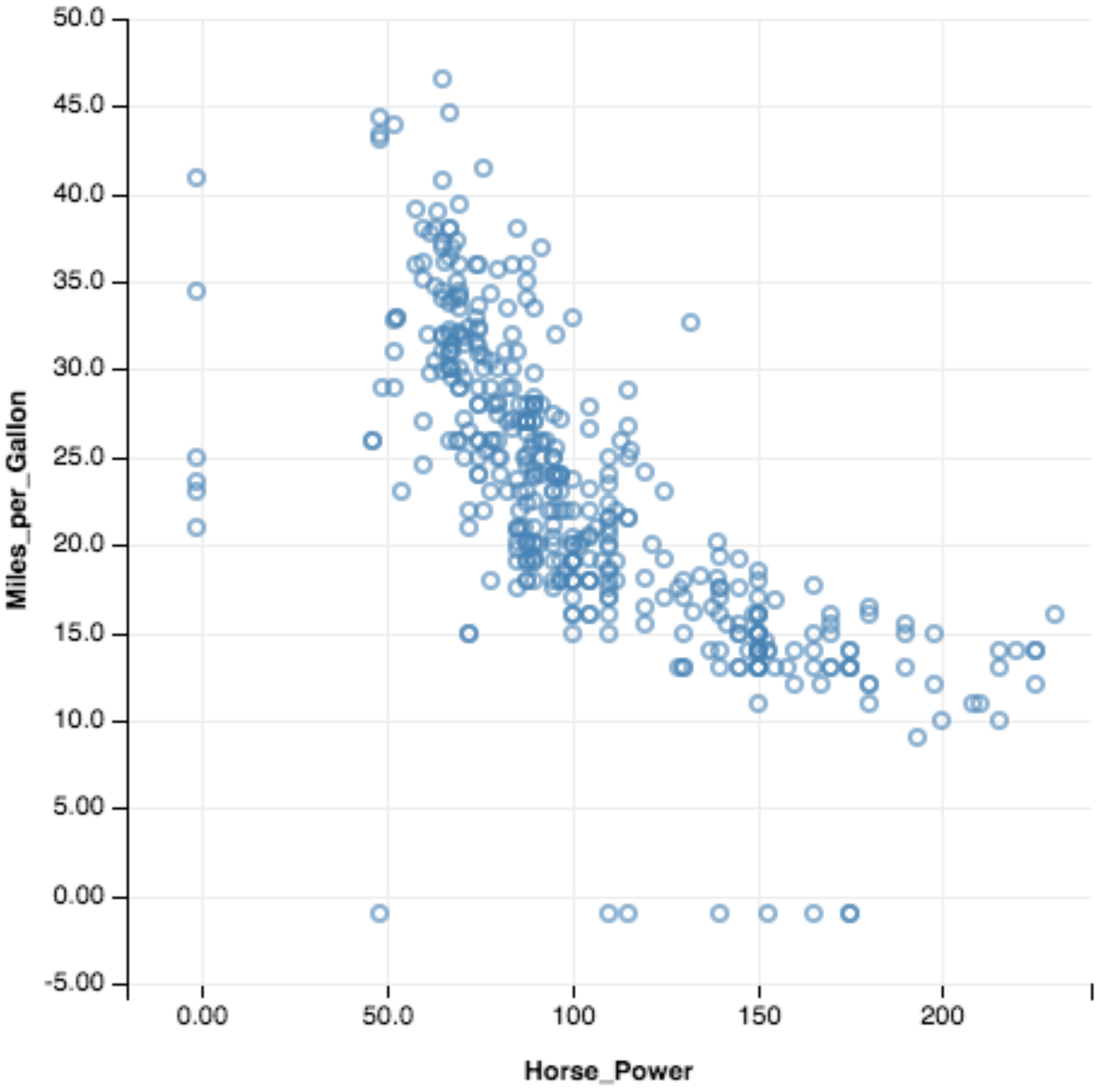

```
{
  "data": {"url": "data/cars.json"},
  "mark": "point",
  "encoding": {
    "x": {"field":"Horse_Power", "type":"Q"},
    "y": {"field":"Miles_per_Gallon", "type":"Q"},
    "color": {"field":"Cylinders", "type":"N"}
  }
}
```

Vega-Lite: Trellis Plot



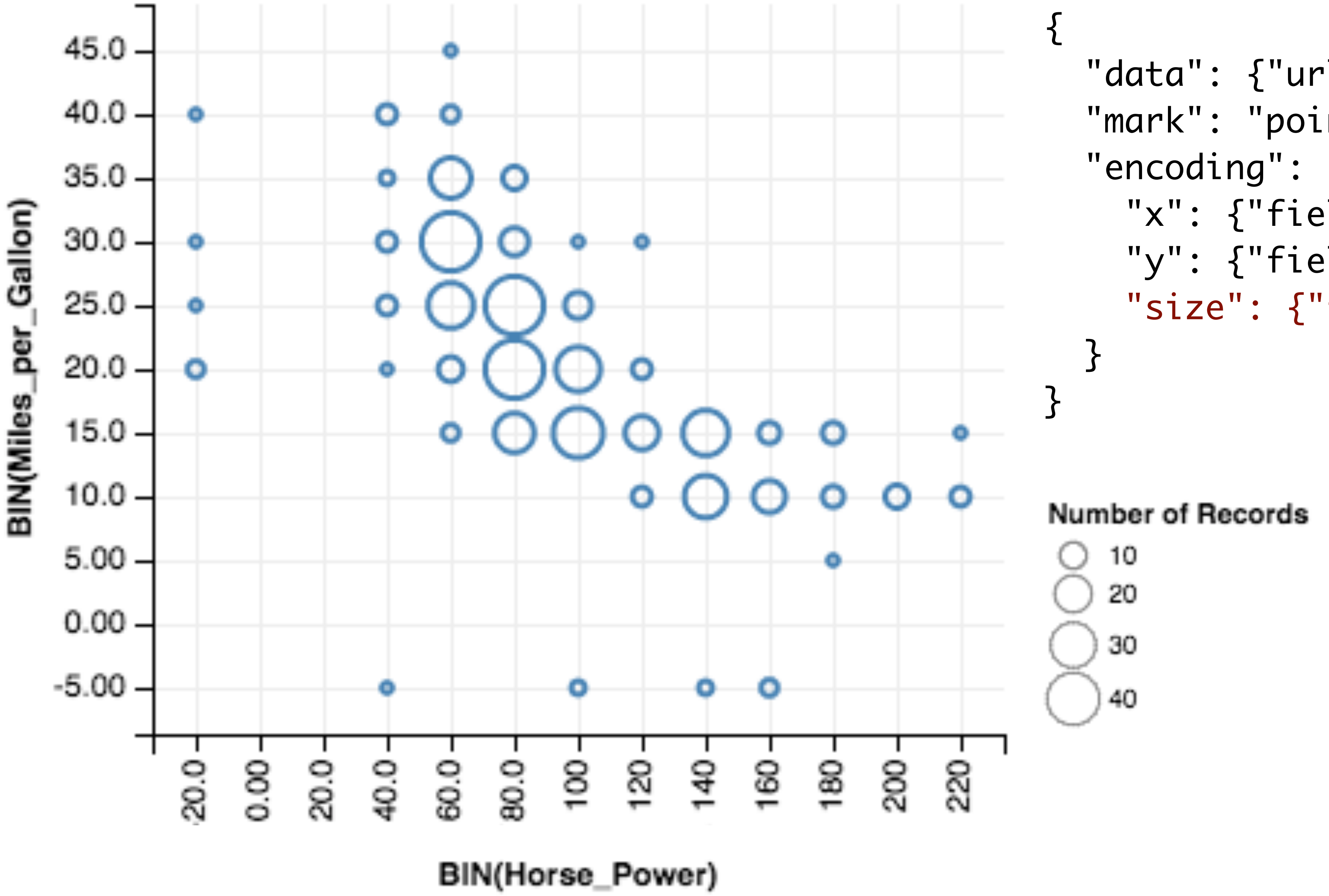

```
{
  "data": {"url": "data/cars.json"},
  "mark": "point",
  "encoding": {
    "x": {"field":"Horse_Power", "type":"Q"},
    "y": {"field":"Miles_per_Gallon", "type":"Q"},
    "column": {"field":"Cylinders", "type":"N"}
  }
}
```

Vega-Lite: Scatter Plot




```
{
  "data": {"url": "data/cars.json"},
  "mark": "point",
  "encoding": {
    "x": {"field":"Horse_Power", "type":"Q"},
    "y": {"field":"Miles_per_Gallon", "type":"Q"}
  }
}
```

Vega-Lite: 2D Histogram

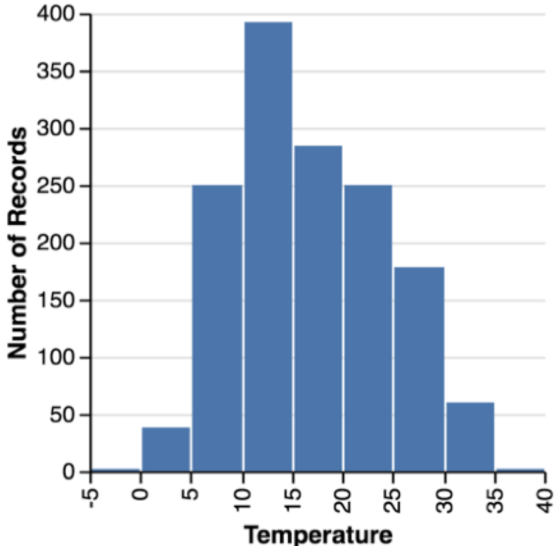



```
{
  "data": {"url": "data/cars.json"},
  "mark": "point",
  "encoding": {
    "x": {"field":"Horse_Power", "type":"Q", "bin":true},
    "y": {"field":"Miles_per_Gallon", "type":"Q", "bin":true},
    "size": {"field":"*", "type":"Q", "aggregate":"count"}
  }
}
```

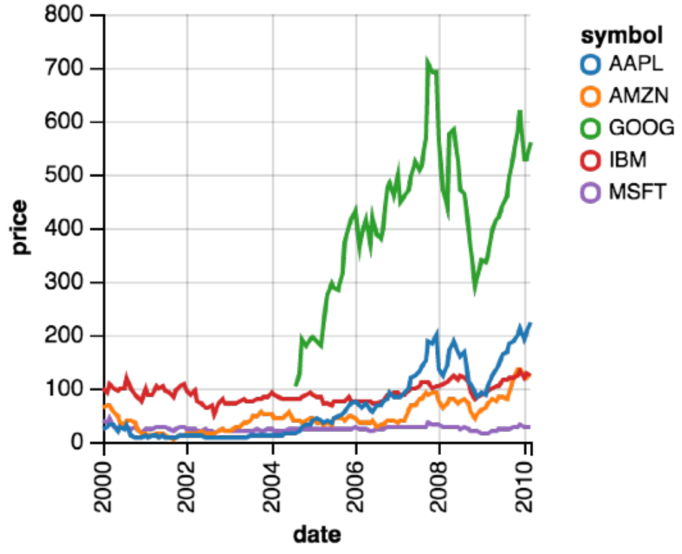
RESEARCH GOAL:

Extend grammars of statistical graphics to enable **multi-view composition** and **interaction**.

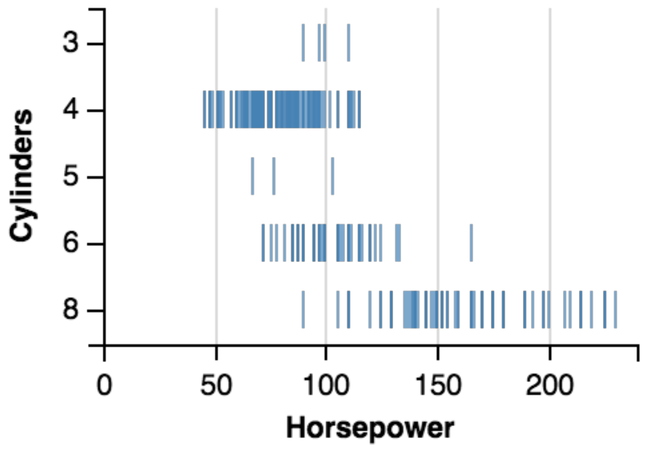
Histogram



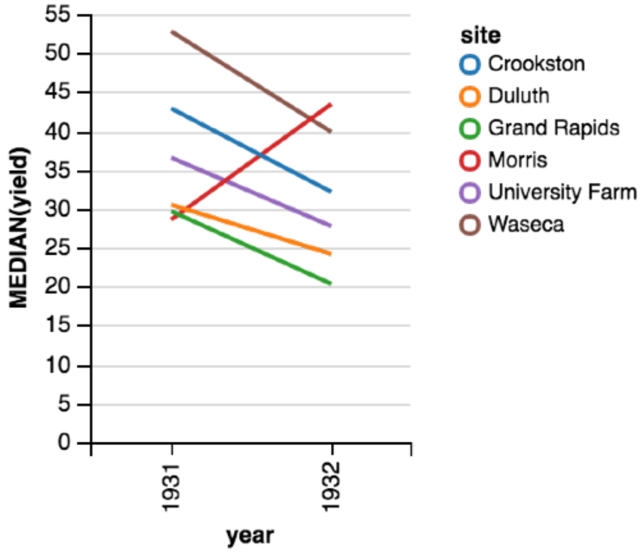
Line Chart



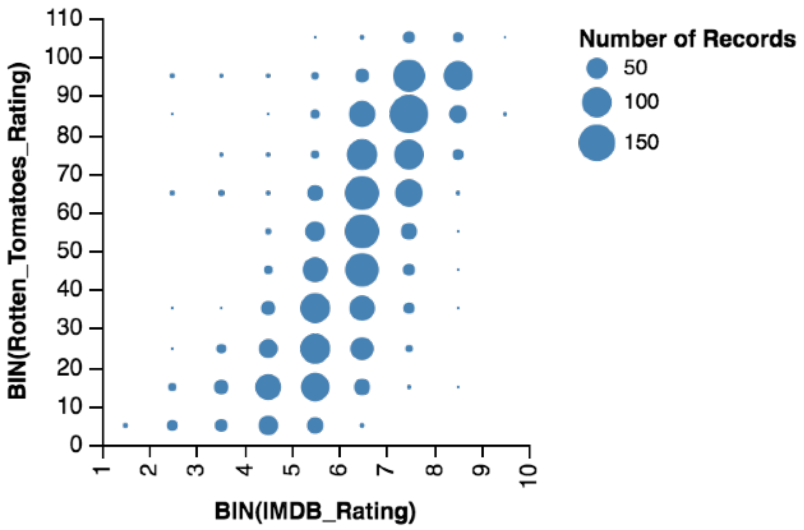
Strip Plot



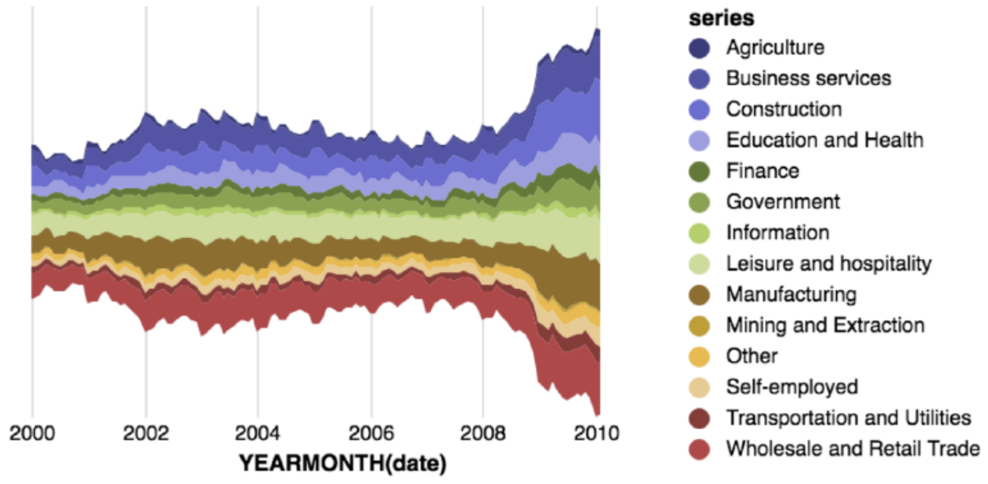
Slope Graph



Binned Scatter Plot

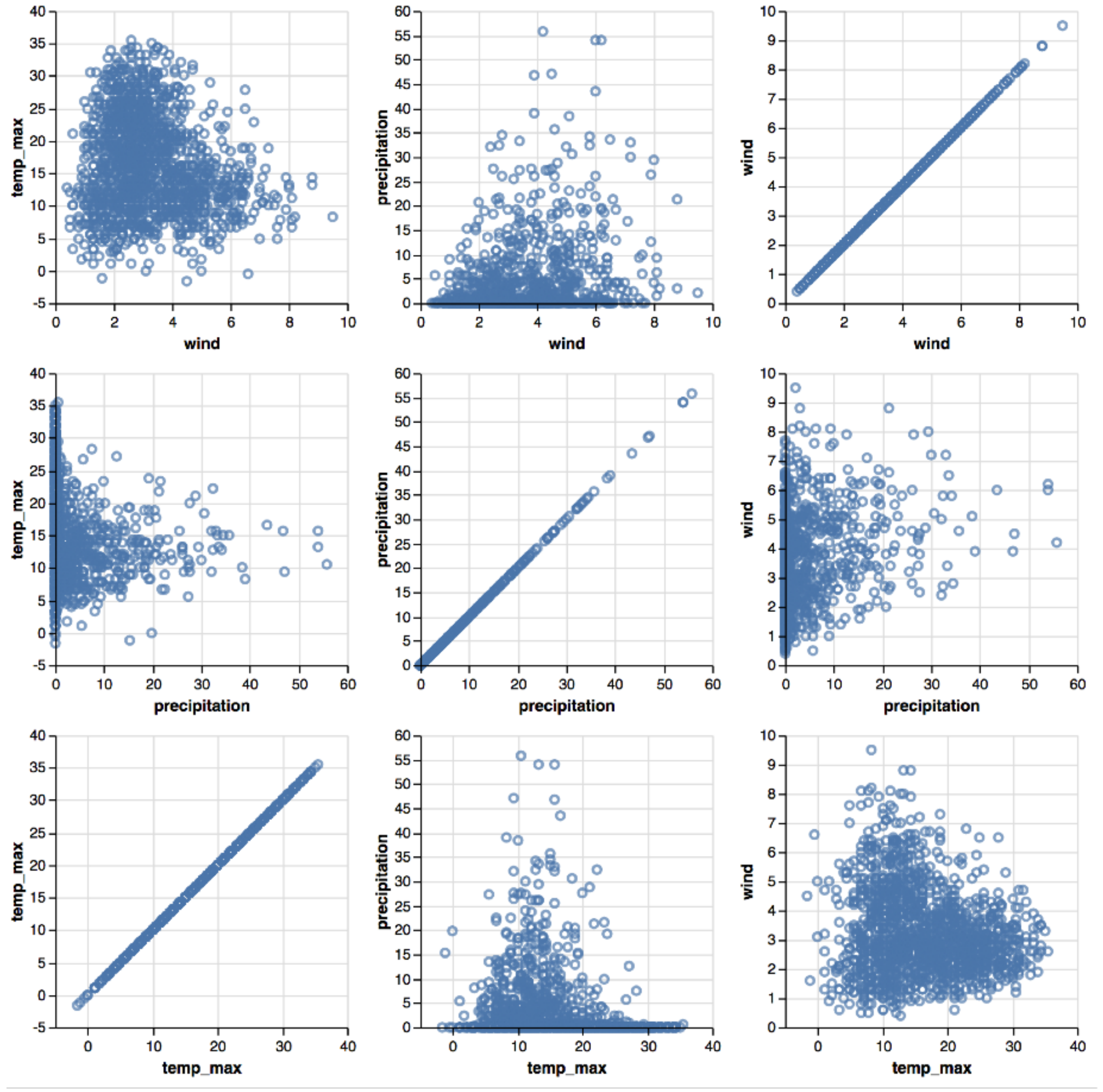


Area Chart

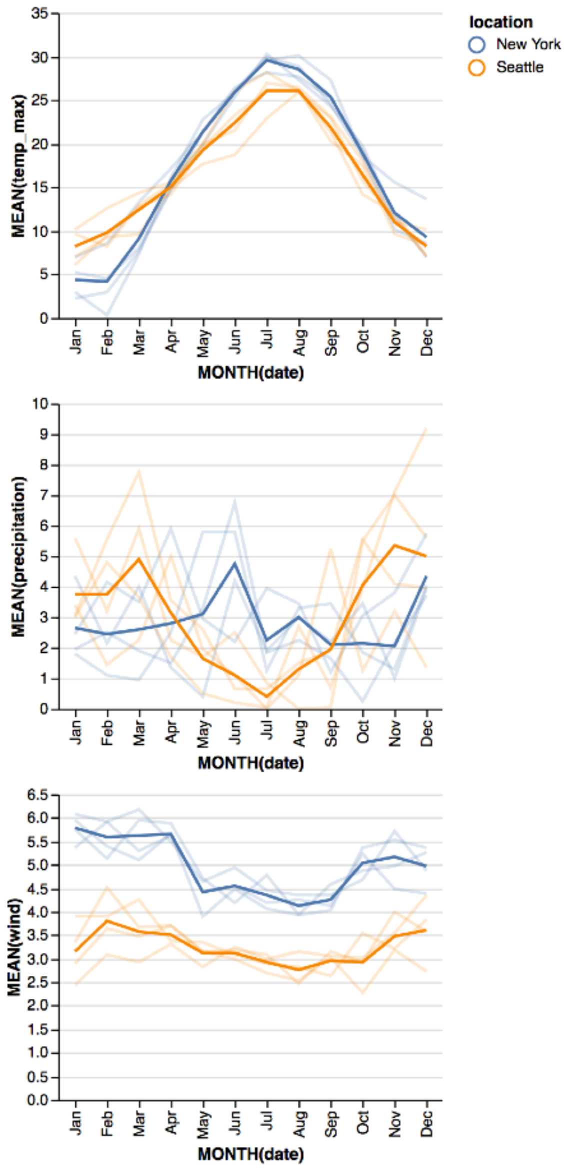


Vega-Lite: A Grammar of Graphics

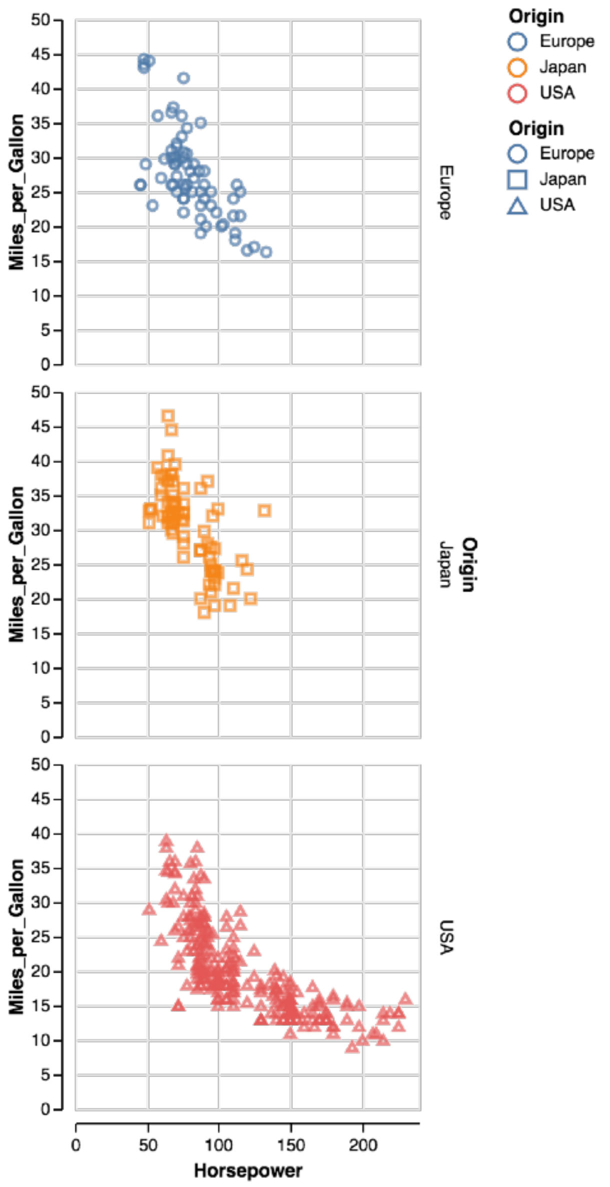
Scatter Plot Matrix



Concatenated & Layered View

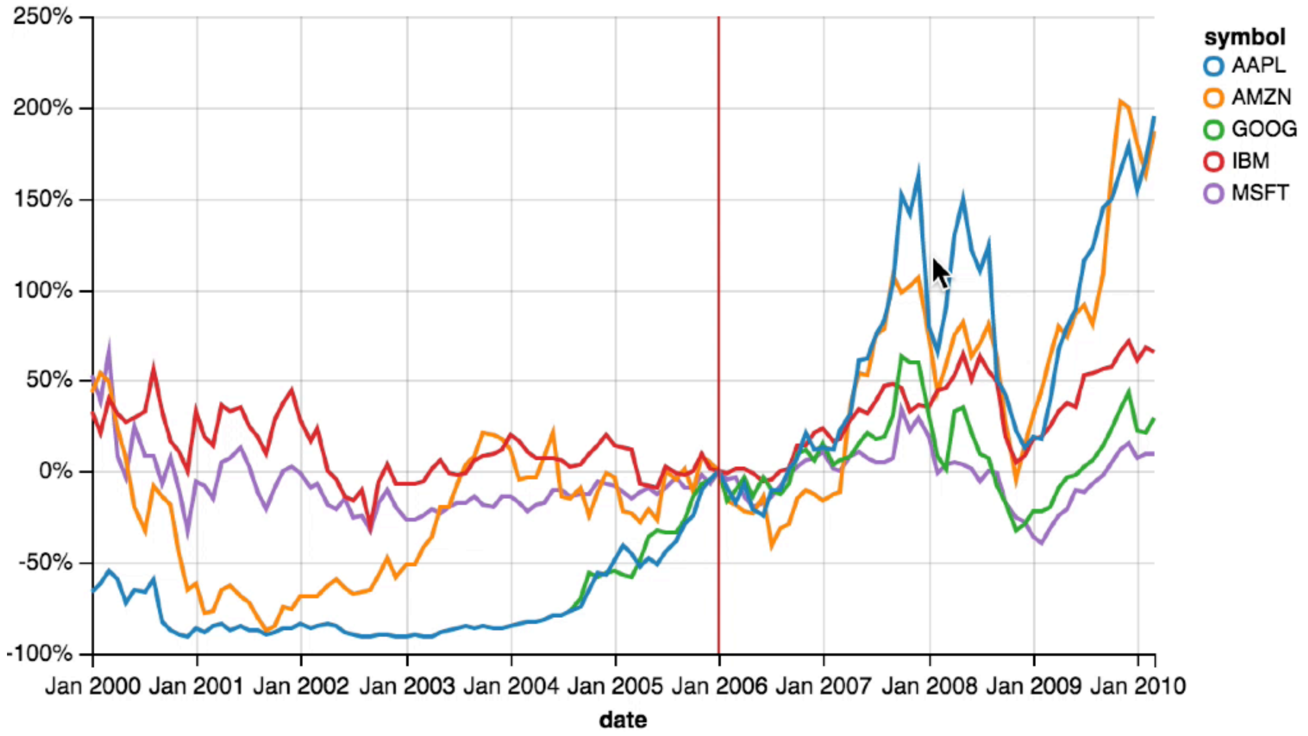


Faceted View

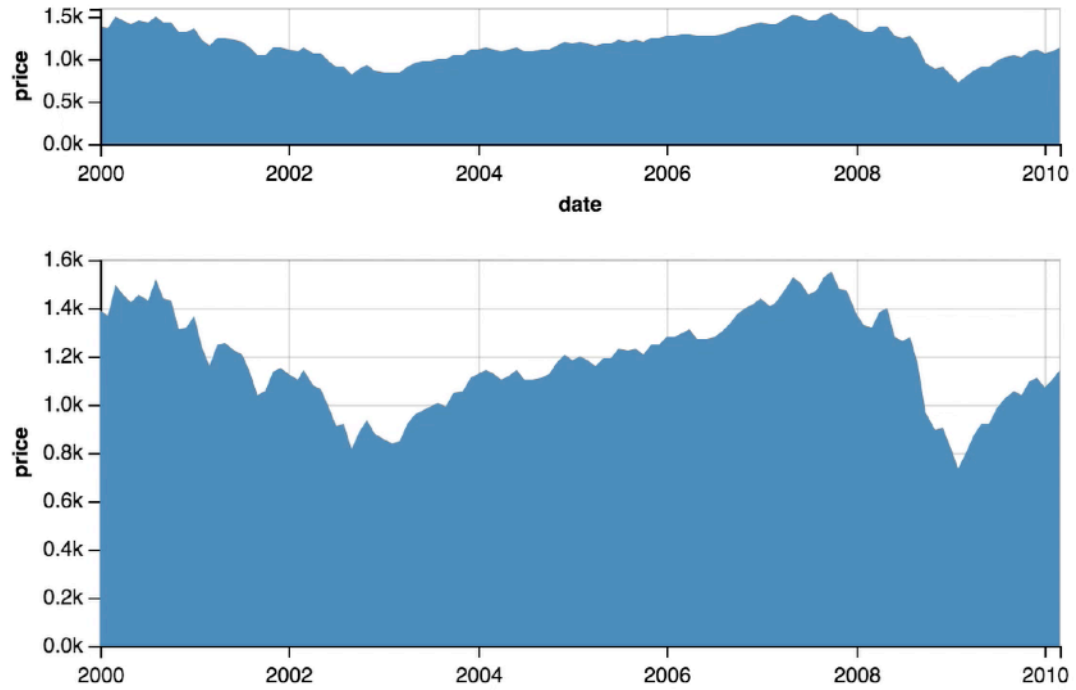


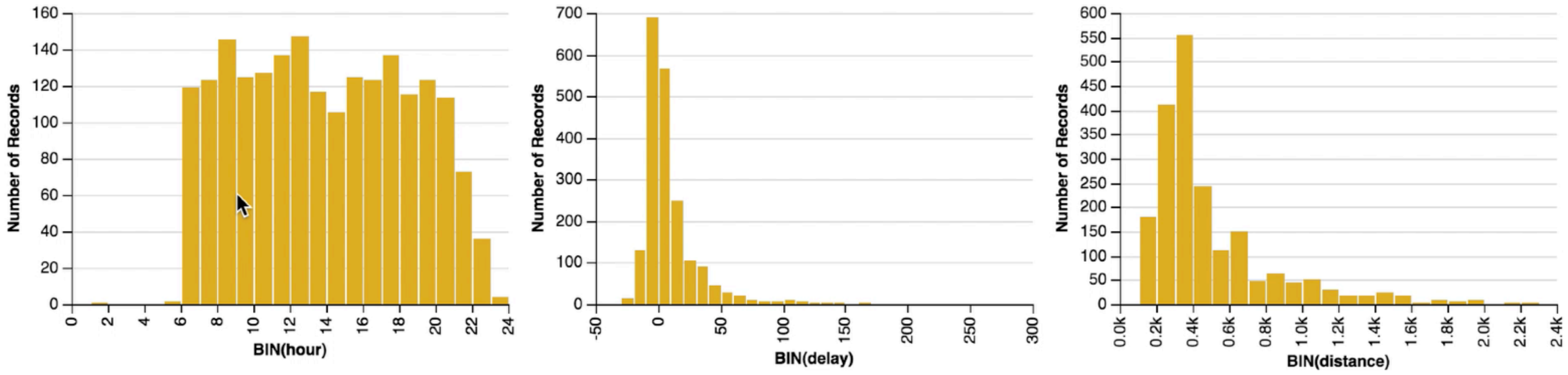
Vega-Lite: A Grammar of **Multi-View** Graphics

Indexed Chart



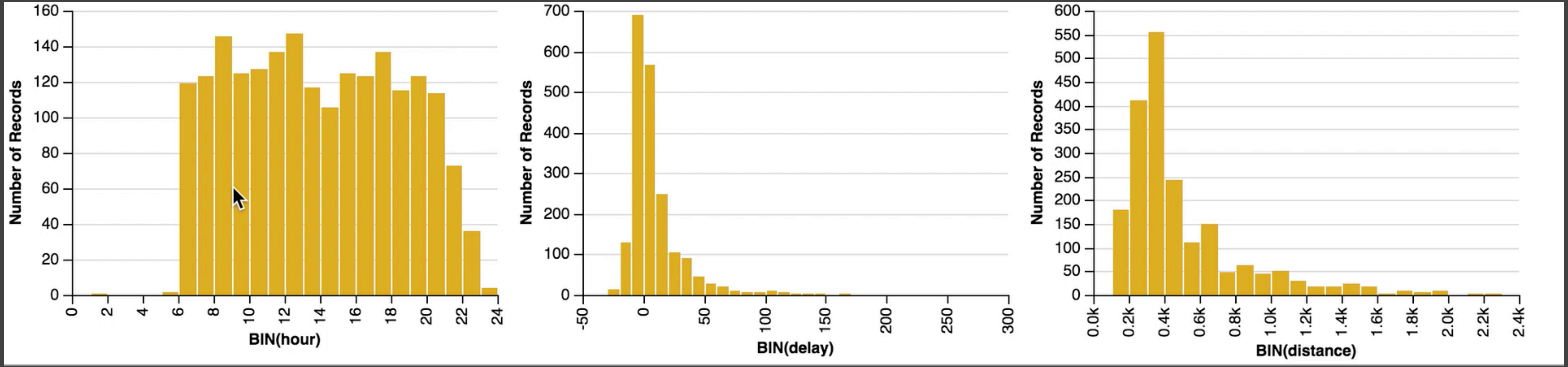
Focus + Context





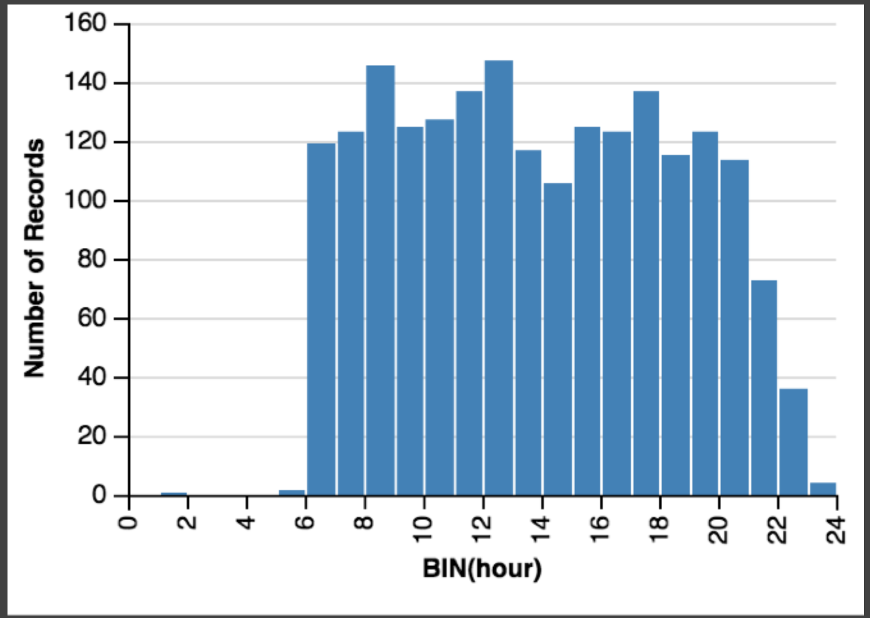
Cross-Filtering

Vega-Lite: A Grammar of Interactive Multi-View Graphics

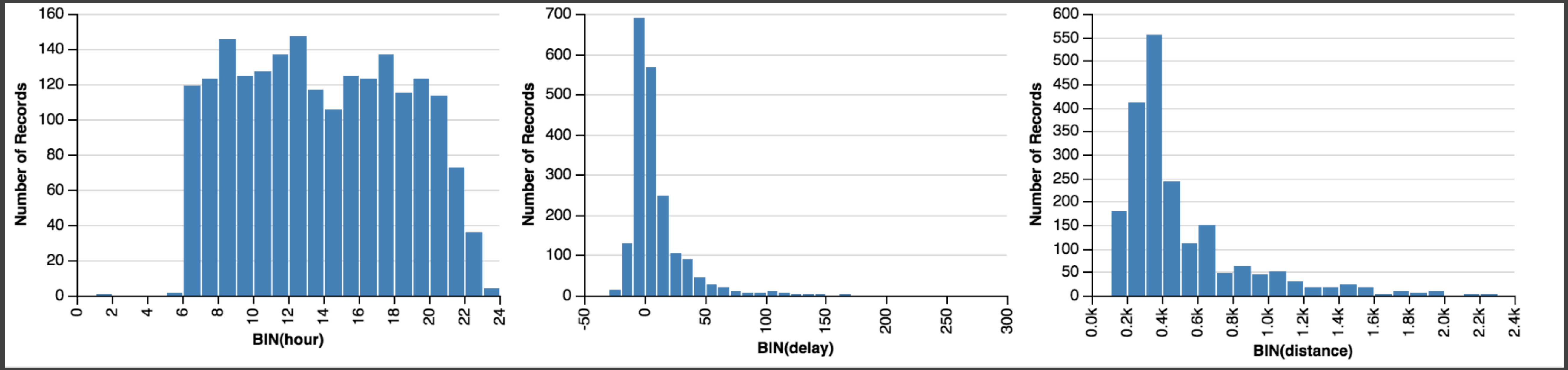


Number of Records
BIN(hour)
Number of Records
BIN(delay)
Number of Records
BIN(distance)

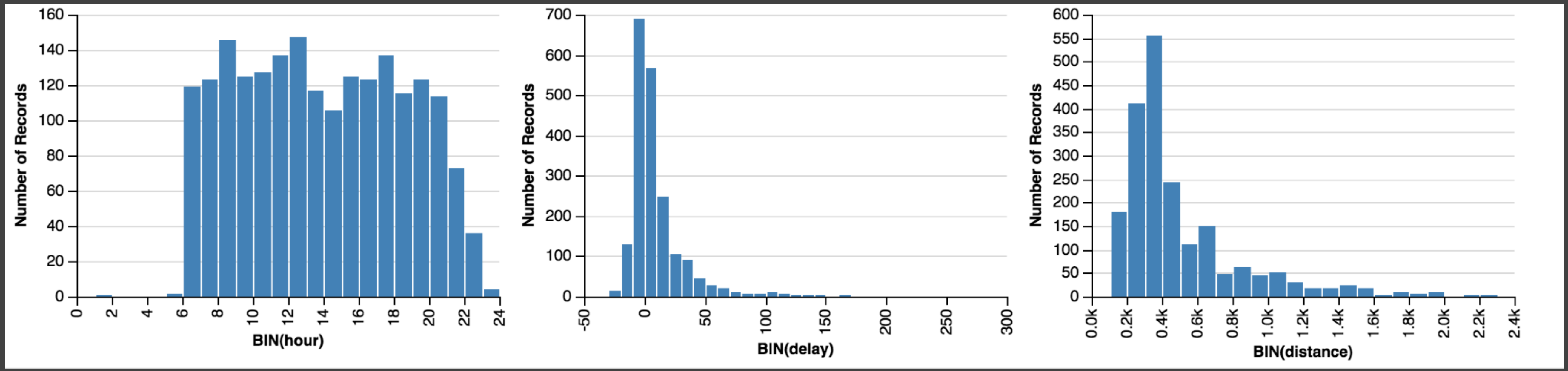
```
{
  "data": {"url": "data/flights.json"},
  "mark": "bar",
  "encoding": {
    "x": {"field": "hour", "bin": true, "type": "Q",},
    "y": {"field": "*", "aggregate": "count", "type": "Q"}
  }
}
```



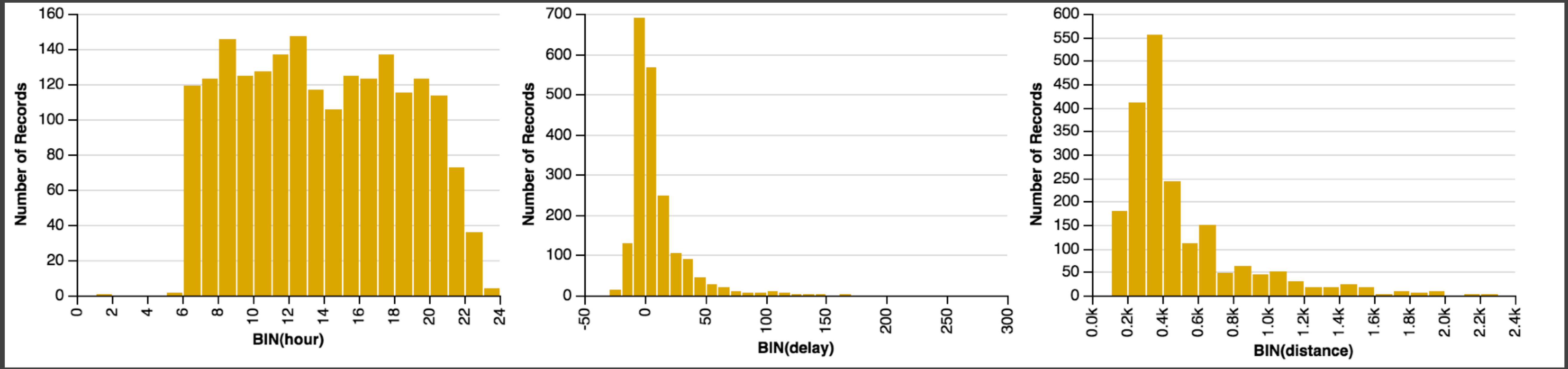
```
{
  "repeat": {"column": ["hour", "delay", "distance"]},
  "spec": {
    "data": {"url": "data/flights.json"},
    "mark": "bar",
    "encoding": {
      "x": {"field": {"repeat": "column"}, "bin": true, "type": "Q"},
      "y": {"field": "*", "aggregate": "count", "type": "Q"}
    }
  }
}
```



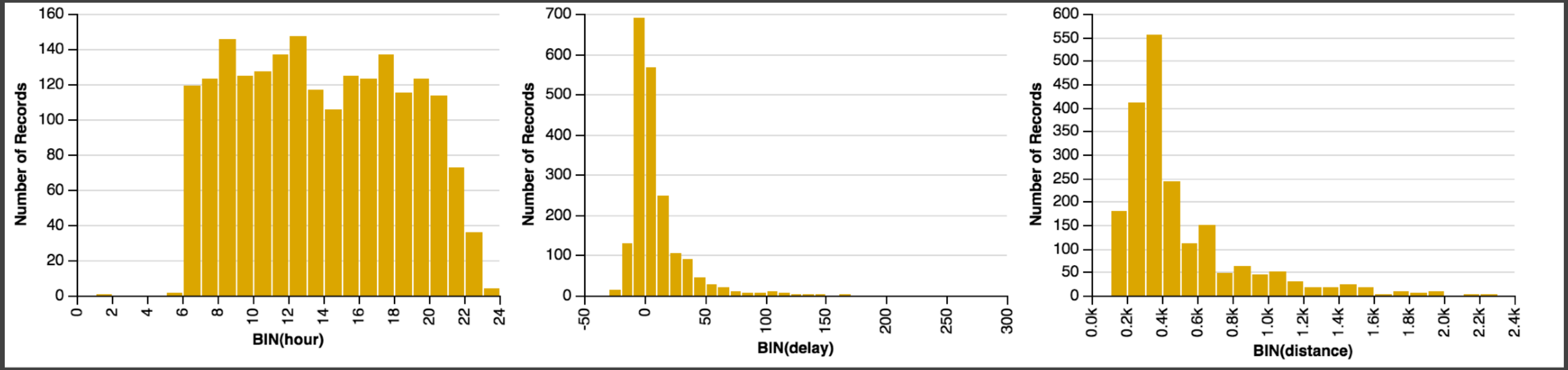
```
{
  "repeat": {"column": ["hour", "delay", "distance"]},
  "spec": {
    "data": {"url": "data/flights.json"},
    "mark": "bar",
    "encoding": {
      "x": {"field": {"repeat": "column"}, "bin": true, "type": "Q"},
      "y": {"field": "*", "aggregate": "count", "type": "Q"}
    }
  }
}
```



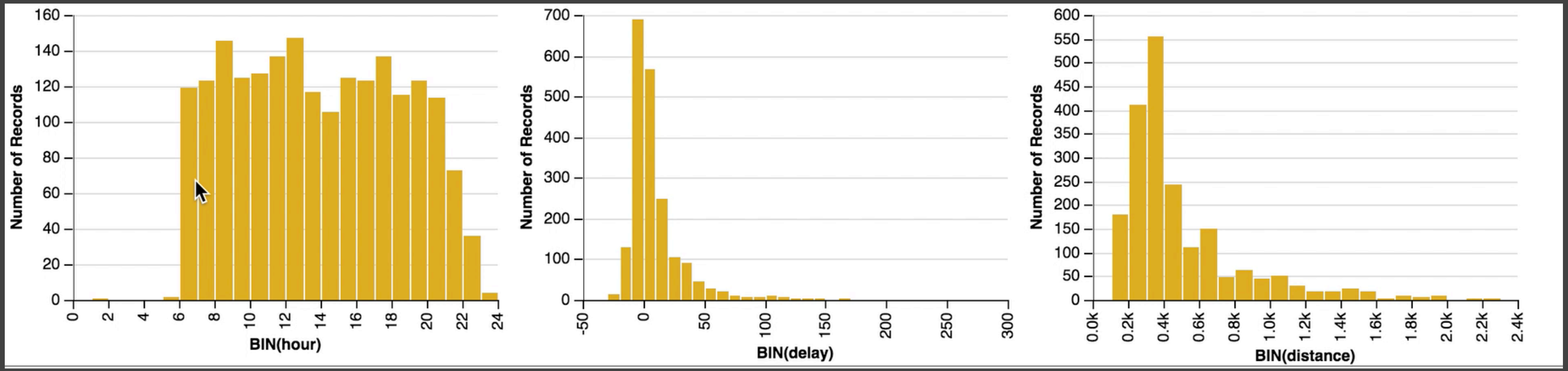
```
{
  "repeat": {"column": ["hour", "delay", "distance"]},
  "spec": {
    "layers": [{
      "data": {"url": "data/flights.json"},
      "mark": "bar",
      "encoding": {
        "x": {"field": {"repeat": "column"}, "bin": true, "type": "Q"},
        "y": {"field": "*", "aggregate": "count", "type": "Q"}
      }
    }, {
      ...,
      "encoding": {
        ...,
        "color": {"value": "goldenrod"}
      }
    }]
  }
}
```



```
{
  "repeat": {"column": ["hour", "delay", "distance"]},
  "spec": {
    "layers": [{
      ...,



    }, {
      ...,

    }]
  }
}
```

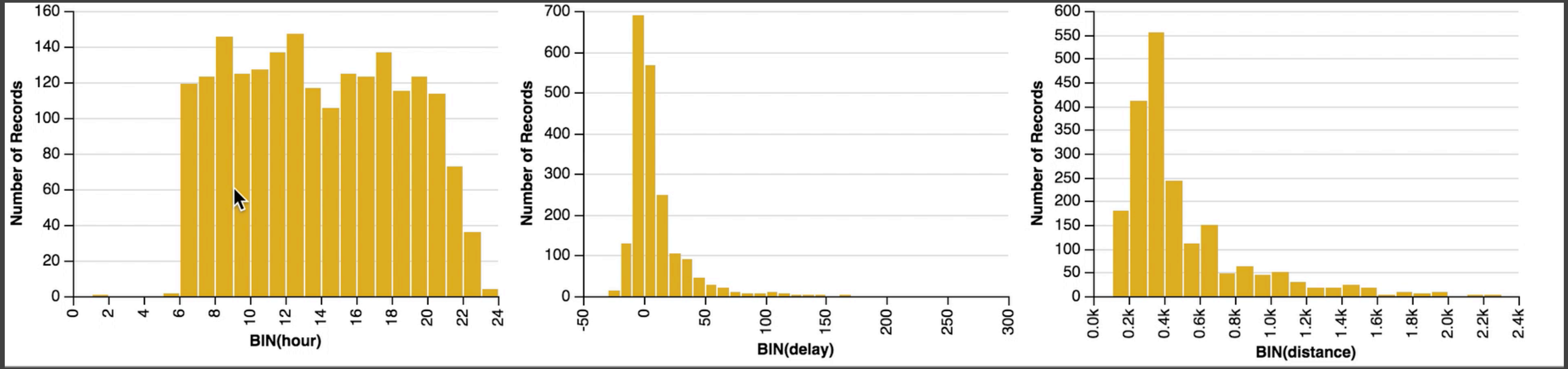


```
{
  "repeat": {"column": ["hour", "delay", "distance"]},
  "spec": {
    "layers": [{
      ...,
      "select": {
        "region": {
          "type": "interval", "project": {"channels": ["x"]}, ...
        }
      }
    }, {
      ...,

    }]
  }
}
```

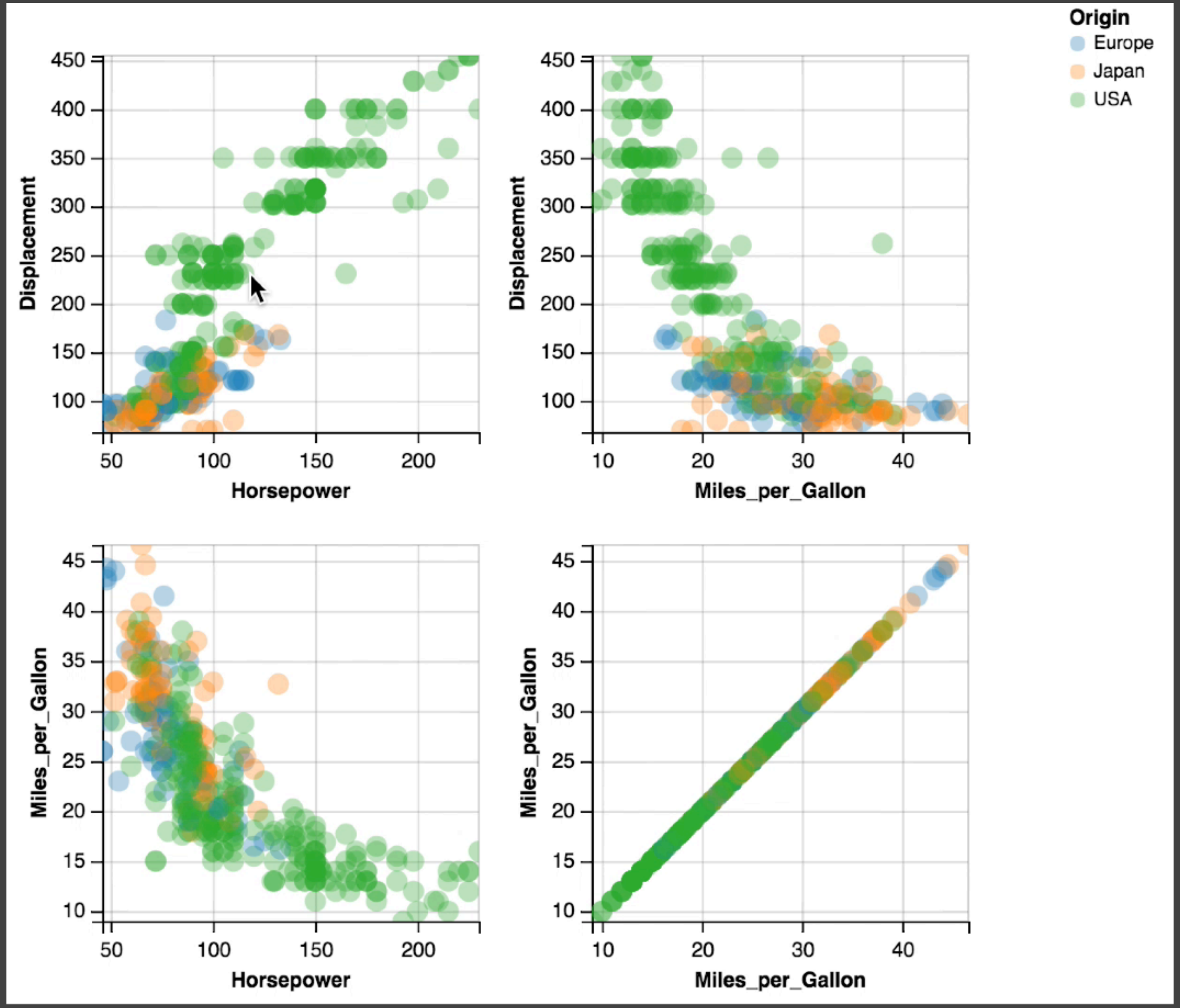


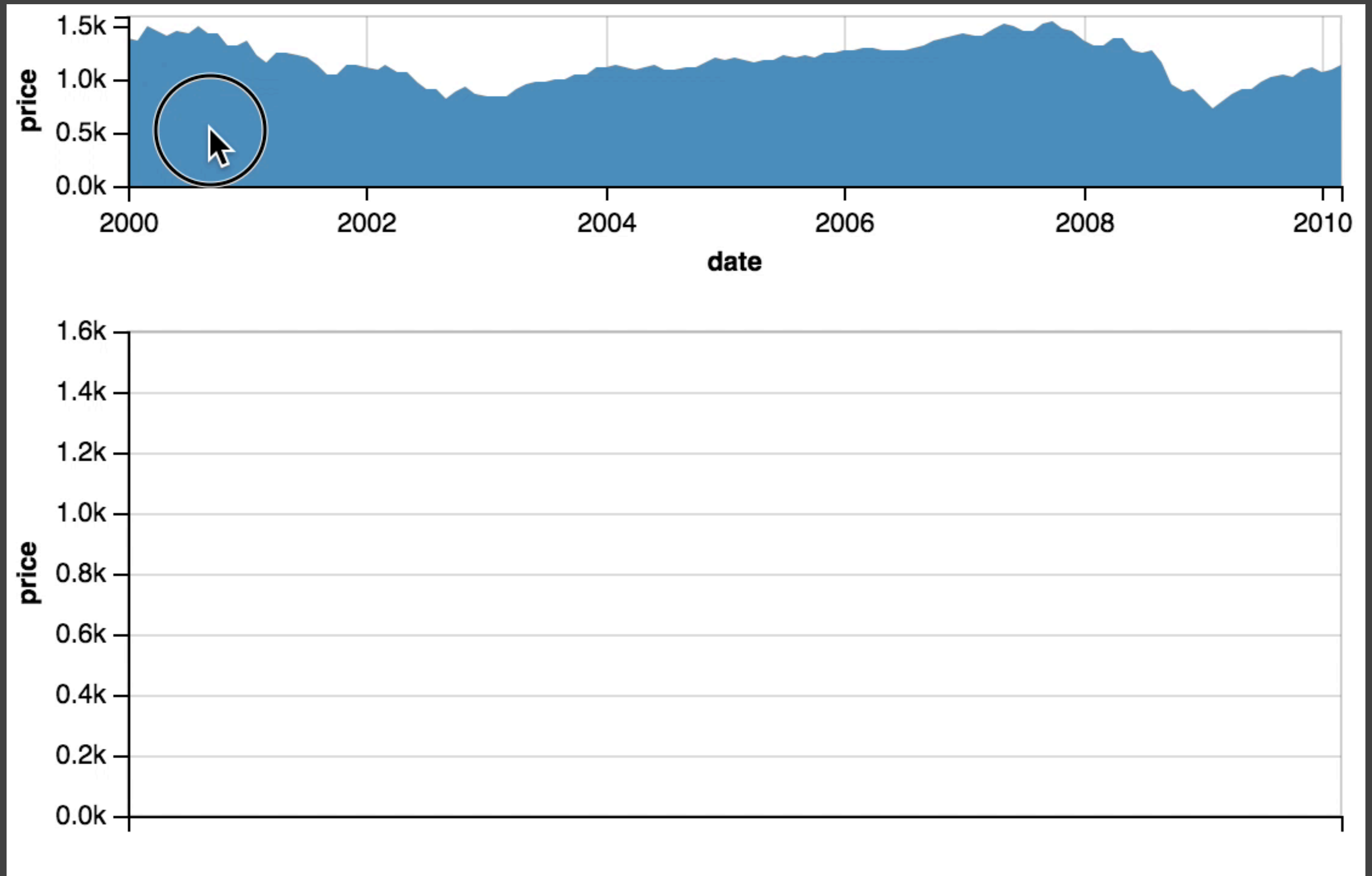
```
{
  "repeat": {"column": ["hour", "delay", "distance"]},
  "spec": {
    "layers": [{
      ...,
      "select": {
        "region": {
          "type": "interval", "project": {"channels": ["x"]}, ...
        }
      }
    }, {
      ...,
      "transform": {"filterWith": "region"}
    }]
  }
}
```

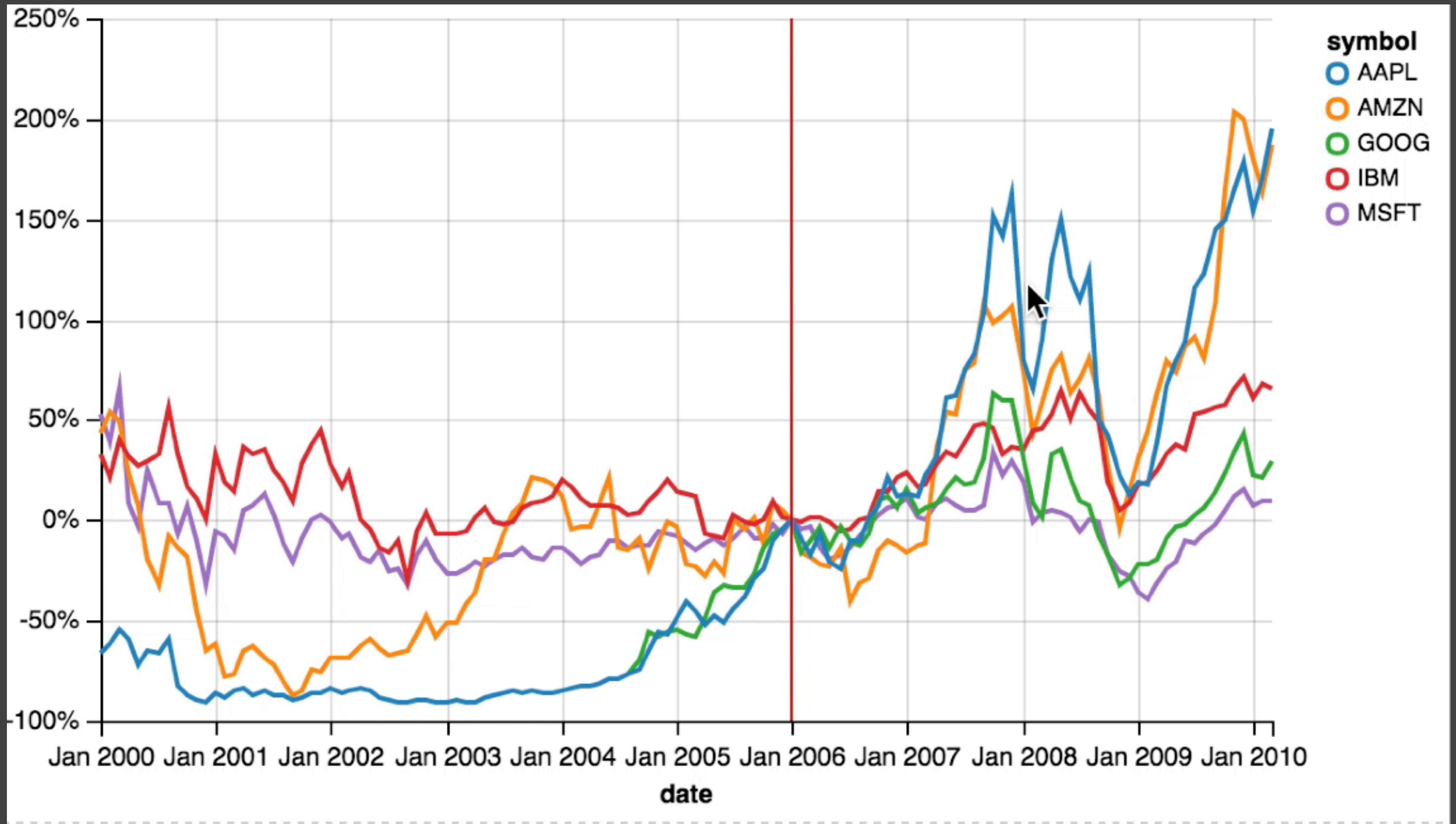
35 Lines of JSON!



Interactive Selections



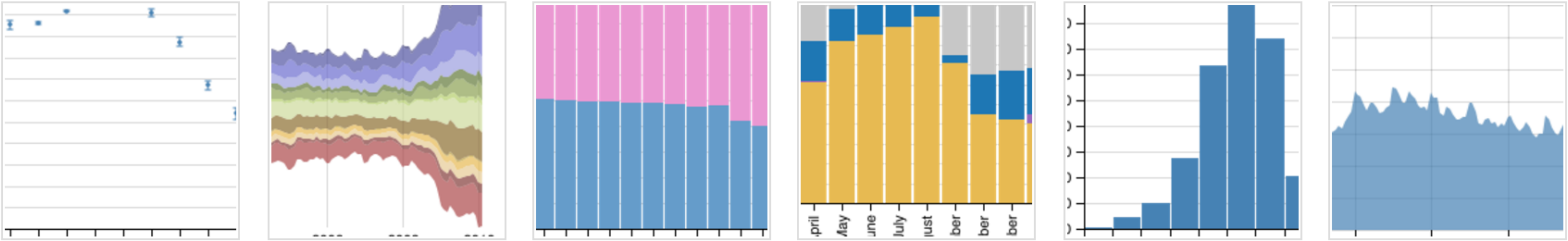




Altair

DECLARATIVE VISUALIZATION IN PYTHON

Declarative Visualization in Python



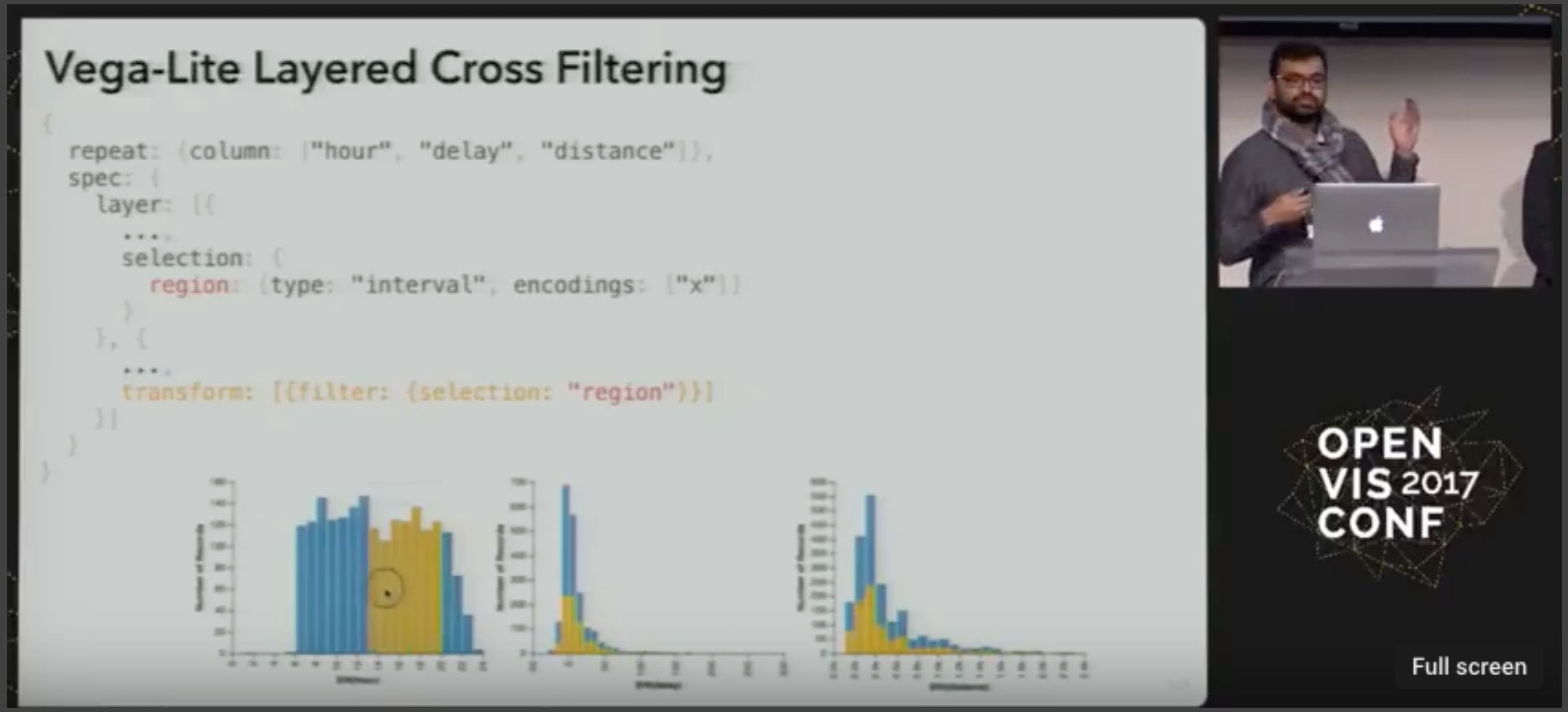
Altair is a declarative statistical visualization library for Python, based on **Vega-Lite**.

With Altair, you can spend more time understanding your data and its meaning. Altair's API is simple, friendly and consistent and built on top of the powerful **Vega-Lite** visualization grammar. This elegant simplicity produces beautiful and effective visualizations with a minimal amount of code.

Altair: Vega-Lite in Python

Led by Jake VanderPlas & Brian Granger

To Learn More…



Vega-Lite: A Grammar of Interactive Graphics, *OpenVis Conf 2017*

youtu.be/9uaHRWj04D4

Altair: Declarative Visualization for Python, *PyData SF 2016*

youtu.be/aRxahWy-ul8

How might we support more
effective data exploration?

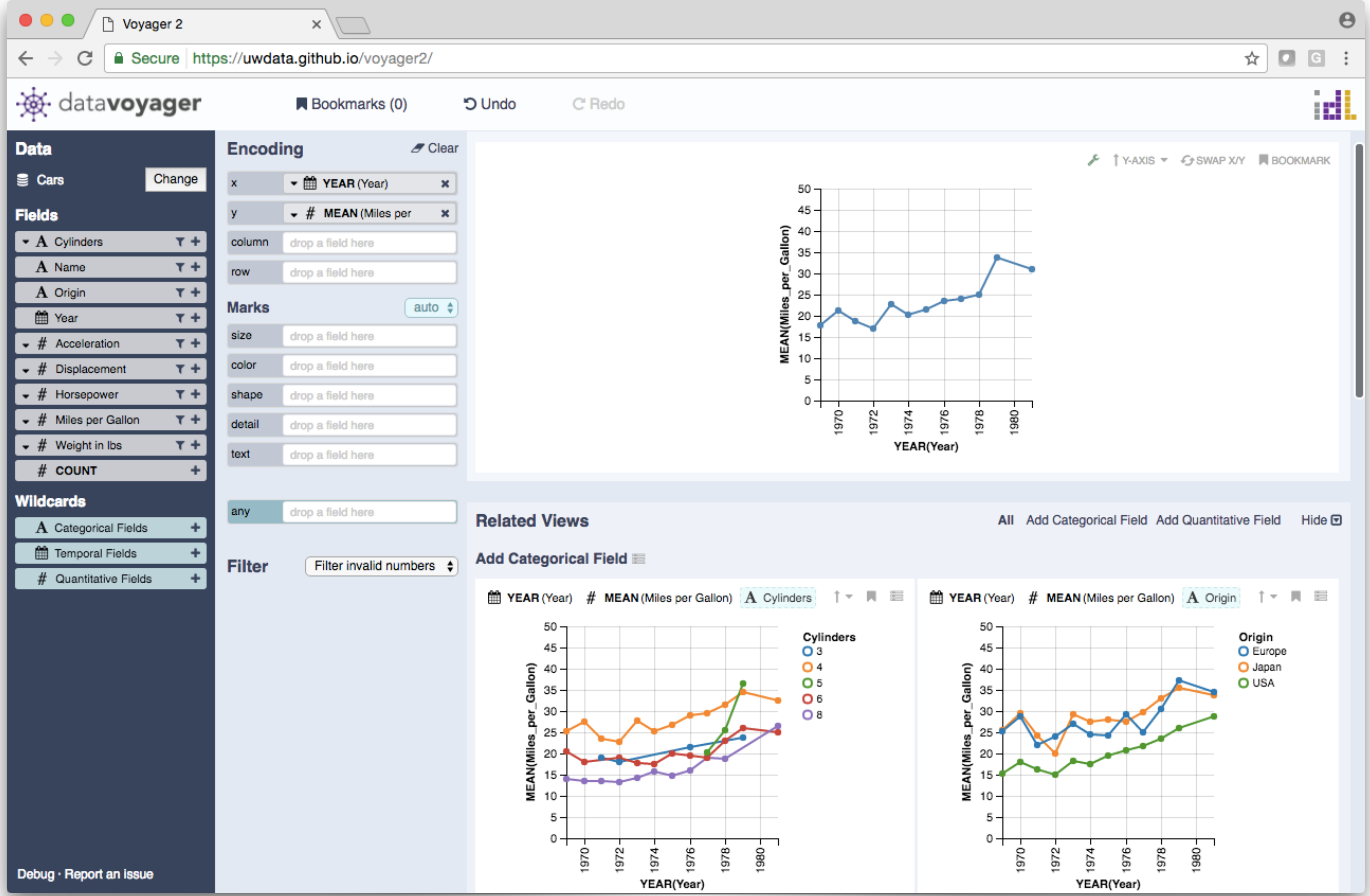
Common analysis pitfalls:

Overlook data quality issues

Fixate on specific relationships

Plus many other cognitive biases

[Heuer 1999, Kahneman 2011, …]



Voyager: Combine Manual Specification with Visualization Recommenders

Key Idea: Augment manual exploration with visualization recommendations sensitive to the user's current focus.

The ultimate goal is to support *systematic consideration* of the data, without exacerbating *false discovery*.

To model a user's search frontier, we *enumerate related Vega-Lite specifications*, seeded by the user's current focus.

Candidate charts are pruned and ranked using models of estimated *perceptual effectiveness*.

Voyager: Combine Manual Specification with Visualization Recommenders

Compared to existing tools, leads to **over 4x more variable sets seen**, and **over 2x more variable sets interacted with**.

“The related view suggestion accelerates exploration a lot.”

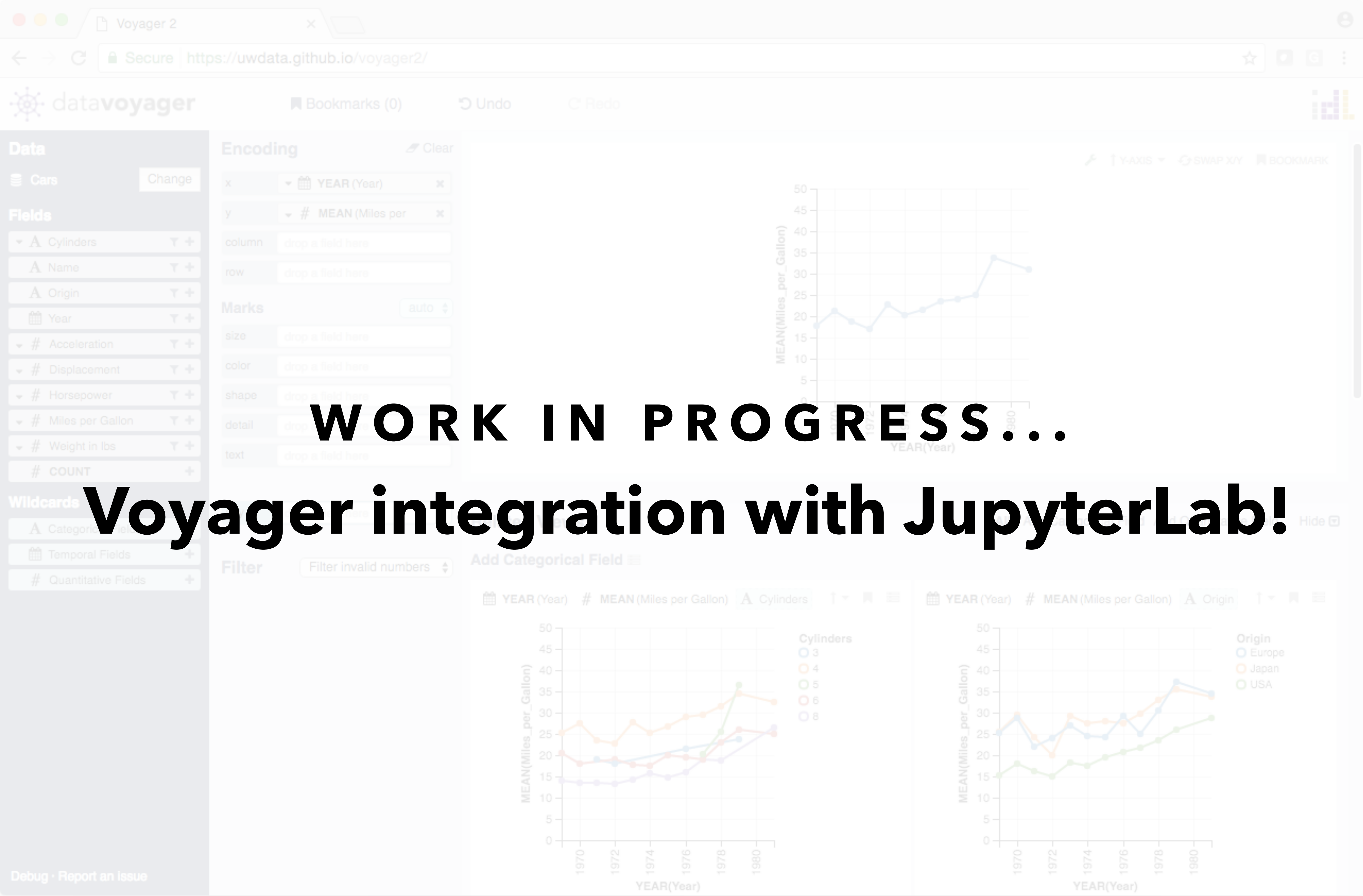
“I like that it shows me what fields to include in order to see a specific graph. Otherwise, I have to do a lot of trial and error and can't express what I wanted to see.”

“These related views are so good but it’s also spoiling that I start thinking less. I’m not sure if that’s really a good thing.”

Voyager: Combine Manual Specification with Visualization Recommenders

WORK IN PROGRESS...

Voyager integration with JupyterLab!



Voyager: Combine Manual Specification with Visualization Recommenders