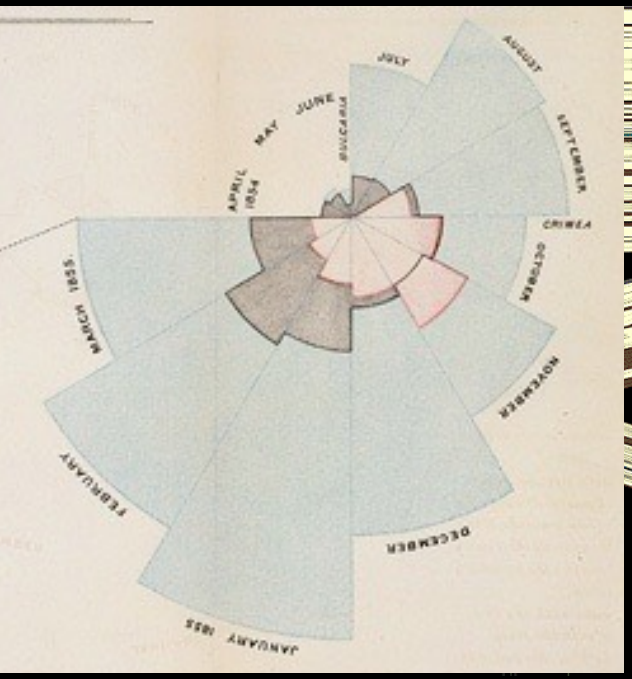
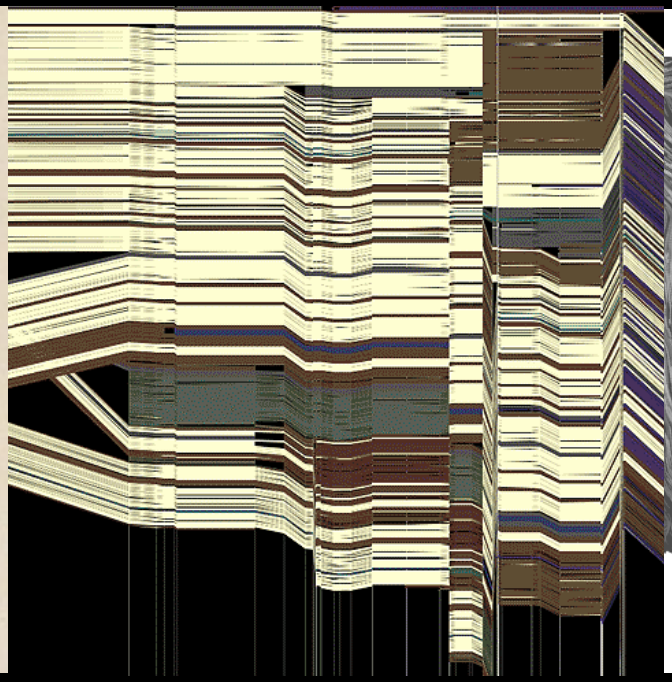
CSE 442 - Data Visualization

Visualization Tools





Jeffrey Heer, Jane Hoffswell Univ. of Washington

How do people create visualizations?

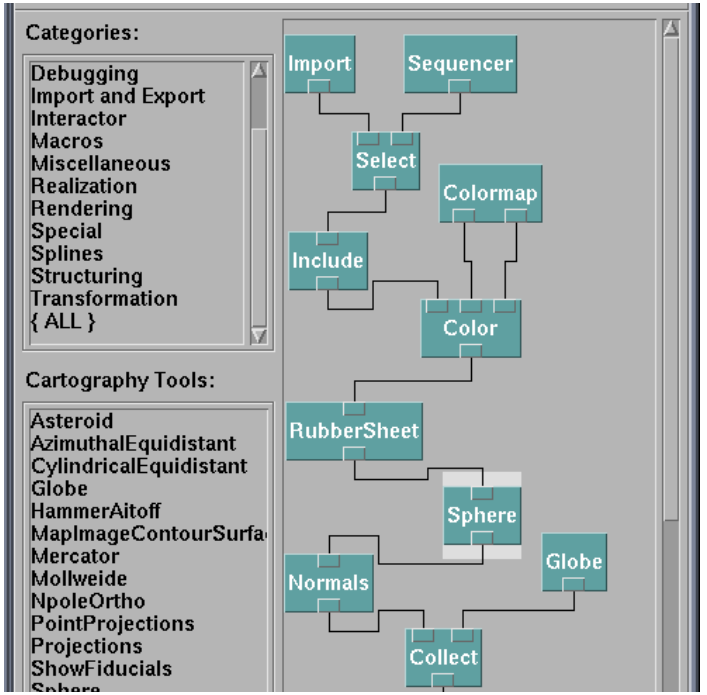


Chart Typology

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

Processing - 0123 Beta

File Edit Sketch Tools Help

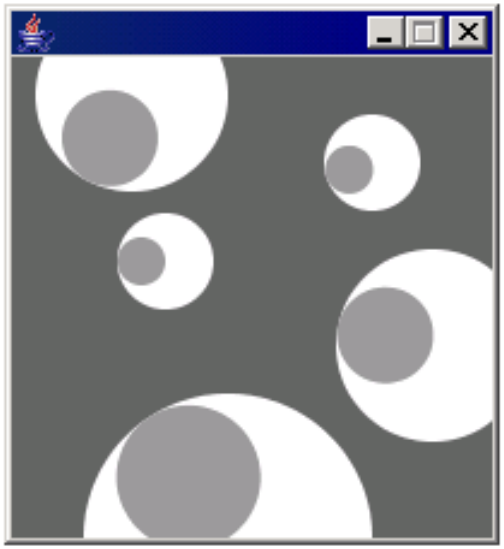
Run

sketch_070126a §

```
    ey = y;
    size = s;
  }

  void update(int mx, int my) {
    angle = atan2(my-ey, mx-ex);
  }

  void display() {
    pushMatrix();
    translate(ex, ey);
    fill(255);
    ellipse(0, 0, size, size);
    rotate(angle);
    fill(153);
    ellipse(size/4, 0, size/2, size/2);
    popMatrix();
  }
}
```



59

http://processing.org

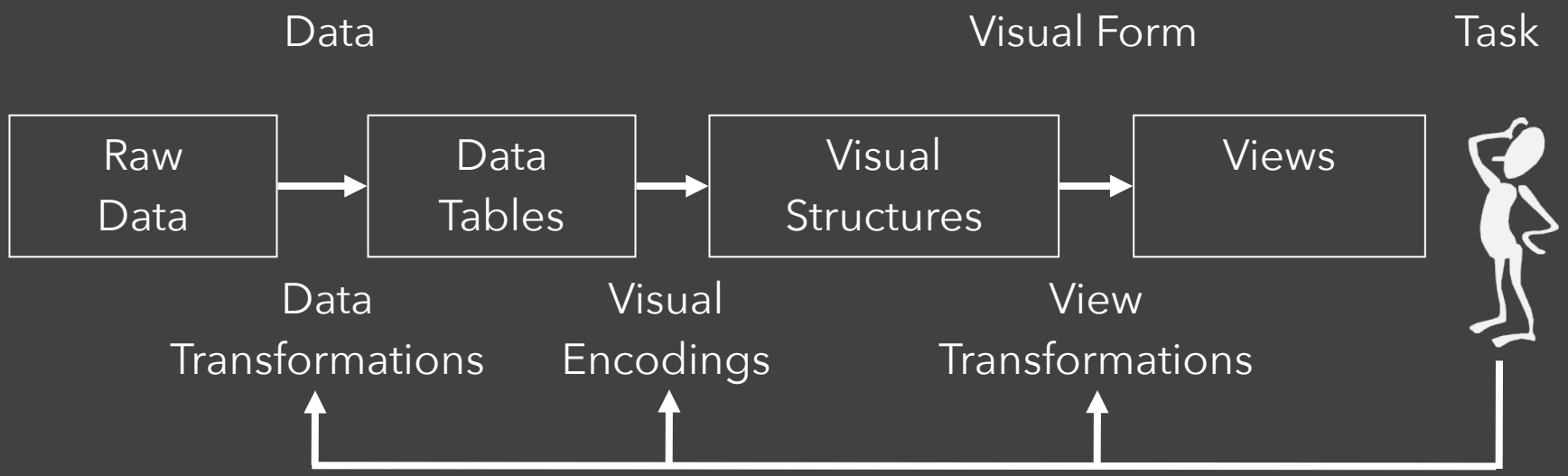

US Air Traffic, Aaron Koblin

Component Architectures

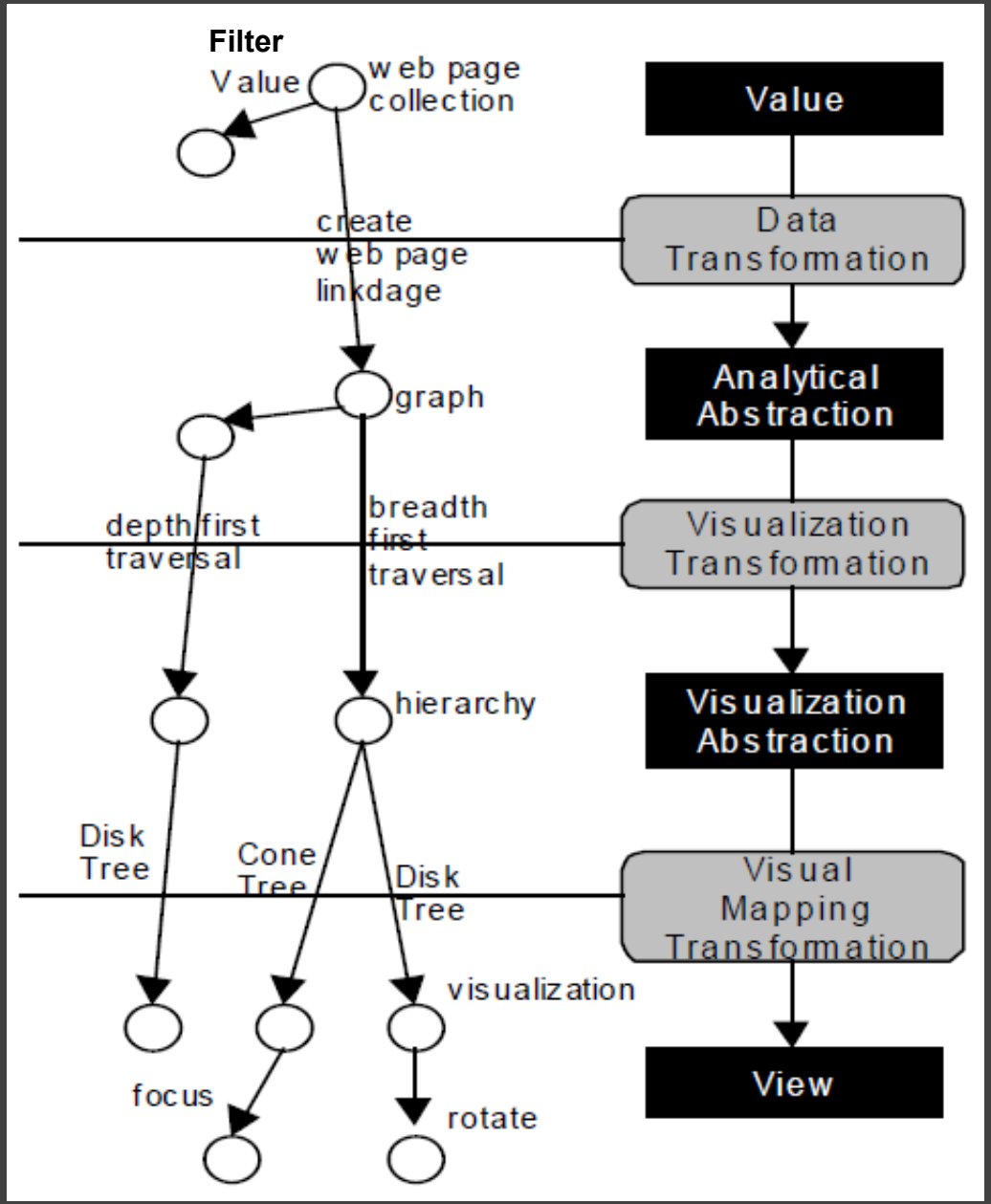
Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D


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

Data State Model
[Chi 98]



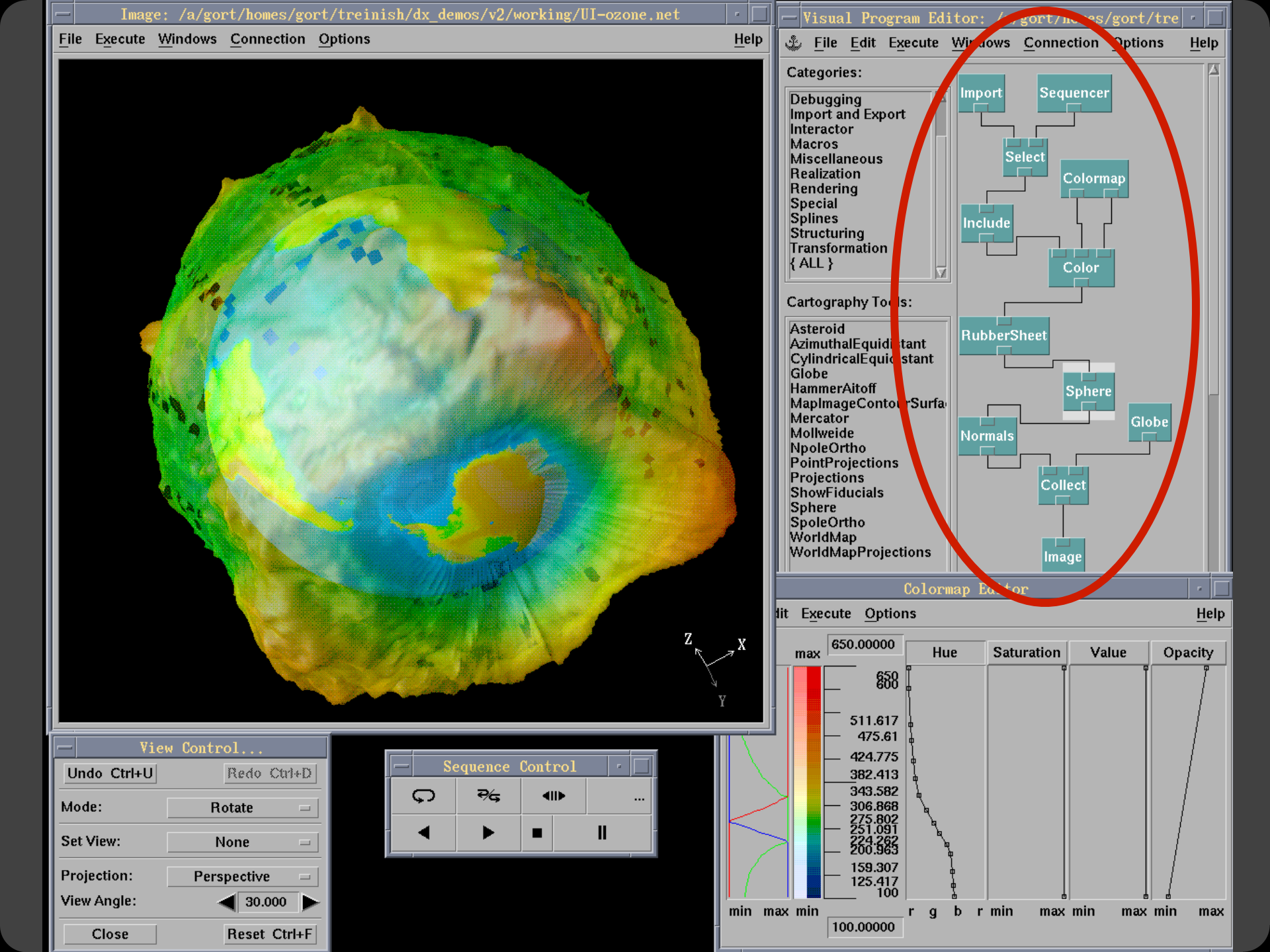
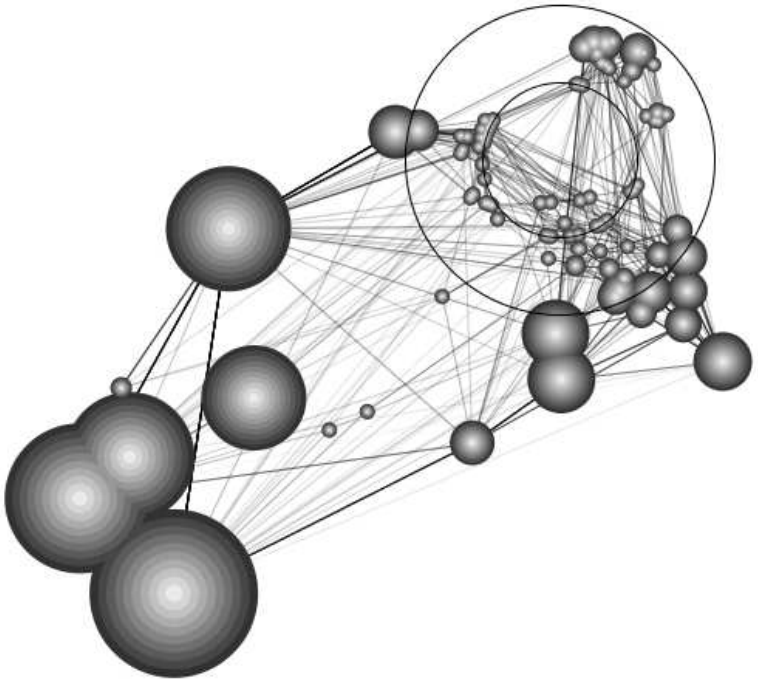


Image: /a/gort/homes/gort/treinish/dx_demos/v2/working/UI-ozone.net
File Execute Windows Connection Options Help
Visual Program Editor:
File Edit Execute Windows Connection Options Help
Categories:
Debugging
Import and Export
Interactor
Macros
Miscellaneous
Realization
Rendering
Special
Splines
Structuring
Transformation
{ ALL }
Cartography Tools:
Asteroid
AzimuthalEquidistant
CylindricalEquistant
Globe
HammerAitoff
MapImageContourSurface
Mercator
Mollweide
NpoleOrtho
PointProjections
Projections
ShowFiducials
Sphere
SpoleOrtho
WorldMap
WorldMapProjections
Import
Sequencer
Select
Colormap
Include
Color
RubberSheet
Sphere
Globe
Normals
Collect
Image
Z
X
Y
Colormap Editor
Edit Execute Options Help
max
650.00000
650
600
511.617
475.61
424.775
382.413
343.582
306.868
275.802
251.091
224.262
200.563
159.307
125.417
100
100.00000
Hue
Saturation
Value
Opacity
min max min r g b r min max min max min max
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

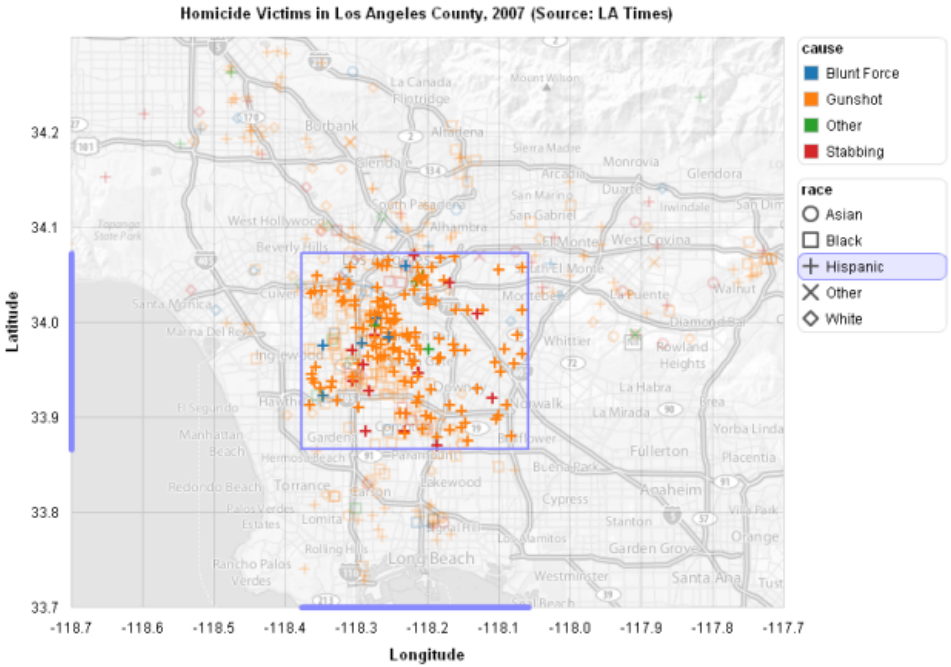
Prefuse & Flare

Operator-based toolkits for visualization design

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



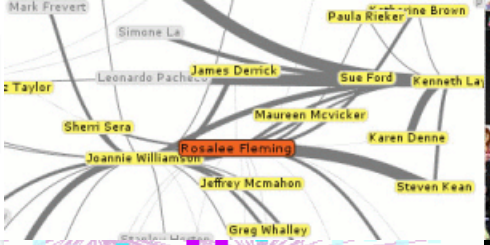
Prefuse (http://prefuse.org)

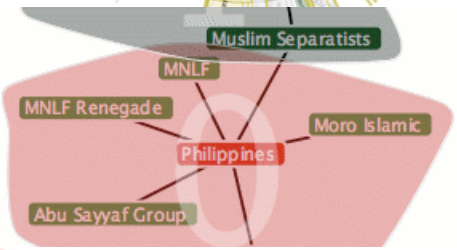


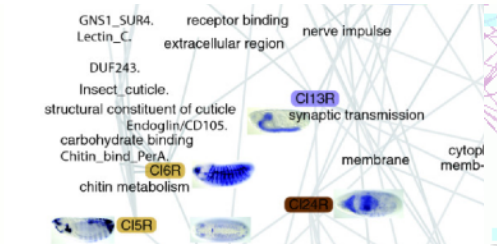
Flare (http://flare.prefuse.org)

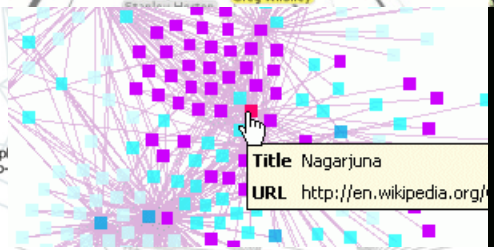

concept
idea
law
plan
kind
principle
model
play
system
plan of action

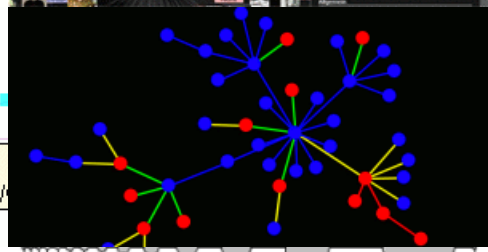

in the
just
at a conference
national park
in
banff

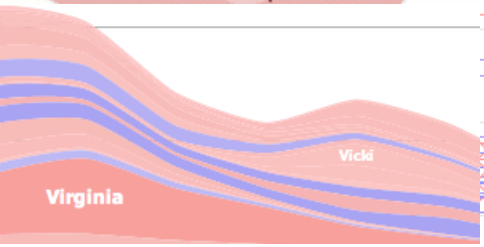

Mark Frevert
Paula Rieker
Simone La
James Derrick
Sue Ford
Kenneth La
Leonardo Pacheco
Sherri Sera
Maureen Mcvicker
Karen Denne
Rosalee Fleming
Joannie Williamson
Jeffrey Mcmahon
Steven Kean
Greg Whalley


Muslim Separatists
MNLF
MNLF Renegade
Moro Islamic
Philippines
Abu Sayyaf Group


GNS1_SUR4.
Lectin_C.
receptor binding
extracellular region
nerve impulse
DUF243.
Insect_cuticle.
structural constituent of cuticle
Endoglin/CD105.
carbohydrate binding
Chitin_bind_PerA.
chitin metabolism
membrane
Cl13R
synaptic transmission
Cl6R
Cl24R
Cl5R


Title Nagarjuna
URL http://en.wikipedia.org/




Vicki
Virginia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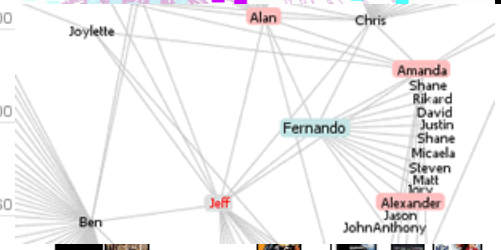
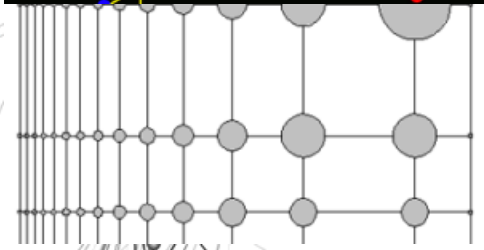
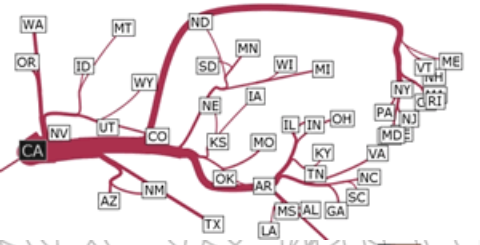

Joylette
Alan
Chris
Amanda
Shane
Rikard
David
Justin
Shane
Micaela
Steven
Matt
Fernando
Jeff
Alexander
Jason
JohnAnthony
Ben




WA
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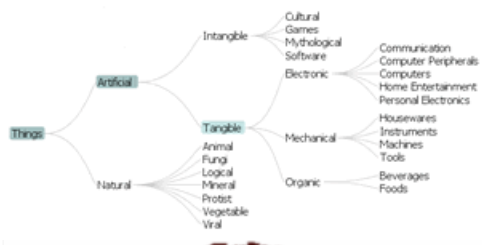
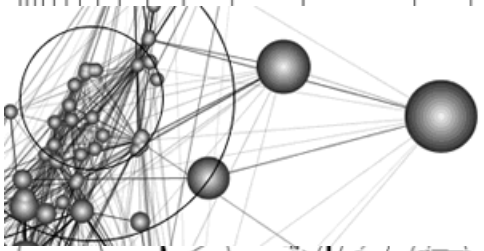
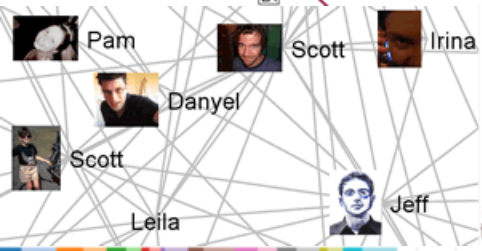
MS
AL
GA
TX
LA


Things
Artificial
Natural
Intangible
Tangible
Electronic
Mechanical
Organic
Cultural
Games
Mythological
Software
Communication
Computer Peripherals
Computers
Home Entertainment
Personal Electronics
Housewares
Instruments
Machines
Tools
Animal
Fungi
Logical
Mineral
Protist
Vegetable
Viral
Beverages
Foods

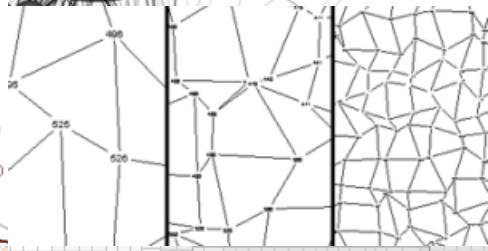

M. M. Salim

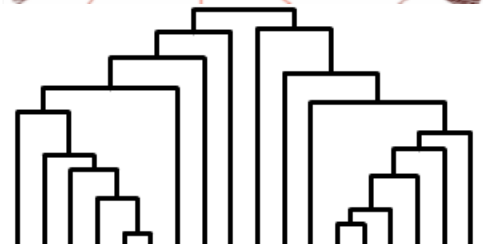


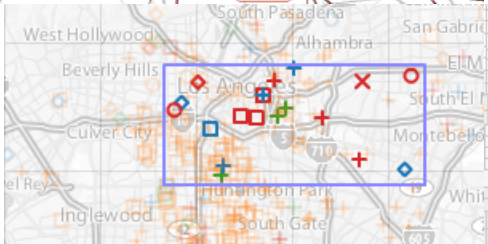

Pam
Scott
Irina
Danyel
Scott
Jeff
Leila

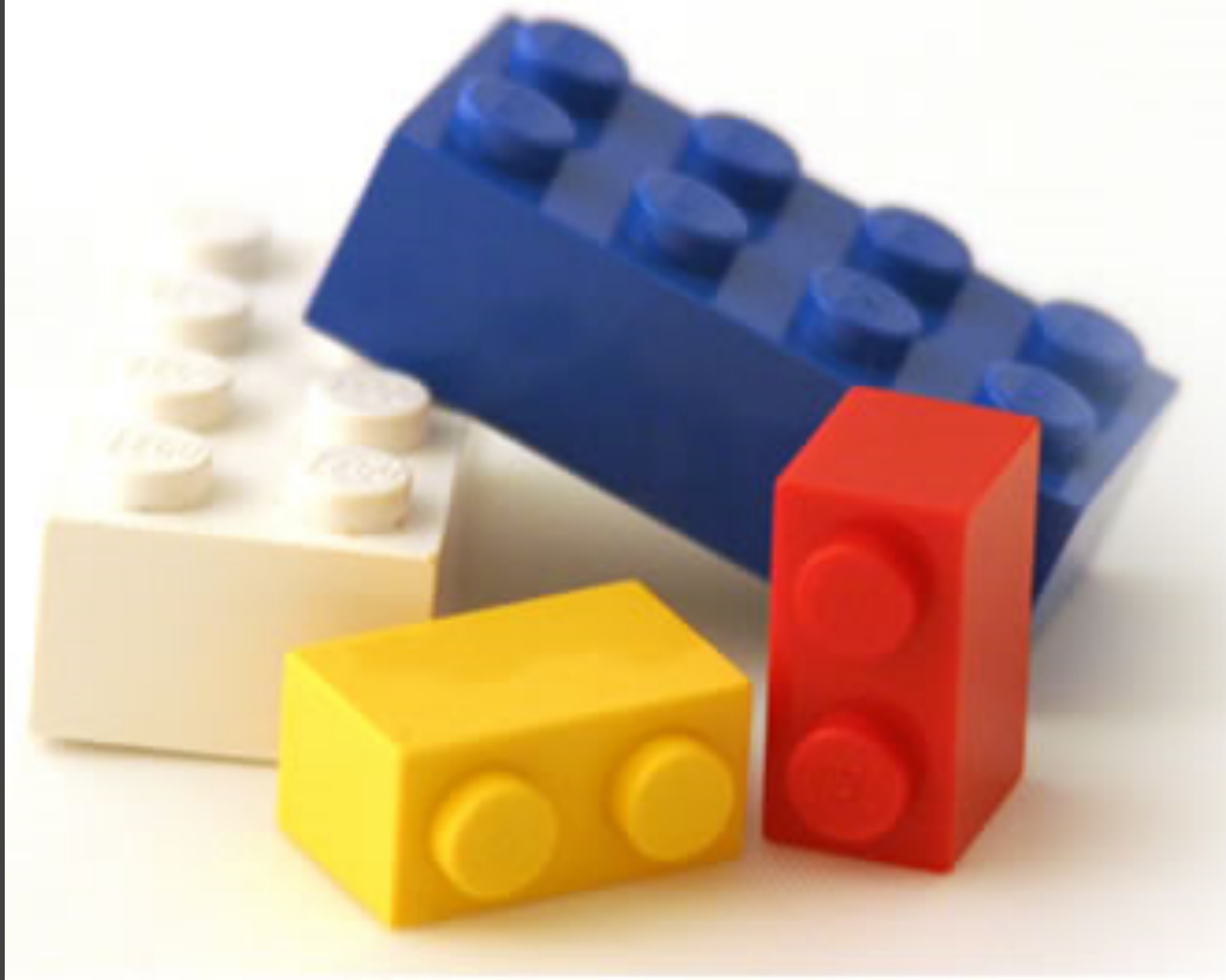

Ideology
Science
Humanities
Technology
Knowledge
Recurring
Historical
The Millenium
Events
Generic
Civilizations
Individuals
S. People
People
Organizations
Relationships
Categories
Natural
Things
Constellations


A. Shaikh
Nawaf Alhazmi
Ami
Lotfi Kamel
H. Z. Moustaoui
Said Bahaji
M. Bakazaoui
Shaikh Said
M. M. Alshehri
Barahmmad
M. Alshehri
Majed Moqed
R. M. Abdullah
Hani Hanjour
Mohamed Atta
M. A. Shehri
W. M. Alshehri
Faisal Al Salmi
Z. Essabar
Ramzi Omar
Sugami
H. Alghamdi


496
525
526




West Hollywood
Beverly Hills
Culver City
Alhambra
South Pasadena
San Gabriel
Montebello
Huntington Park
Inglewood
South Gate



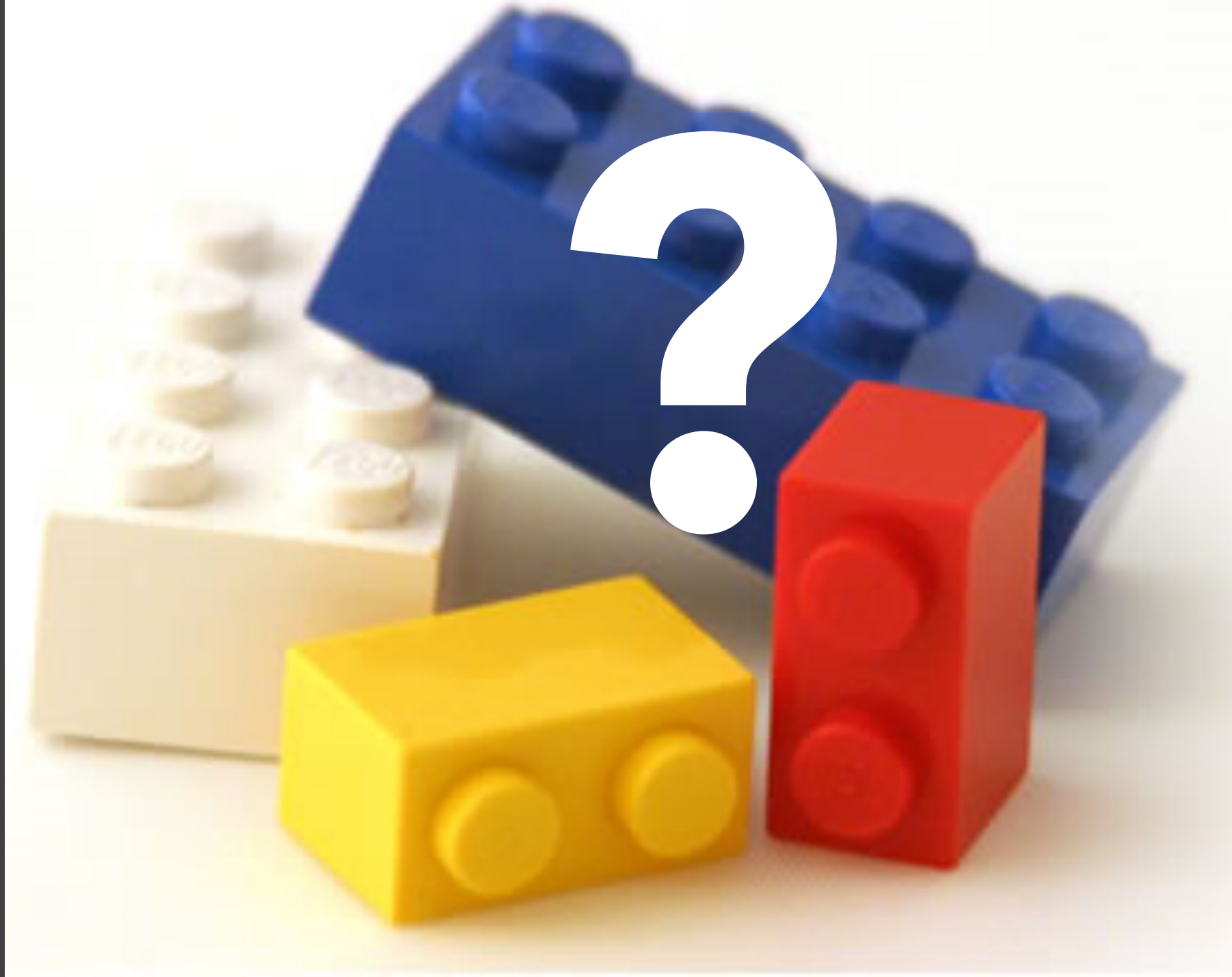


Chart Typologies

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.

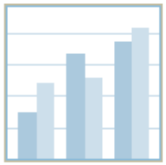
Learn more

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

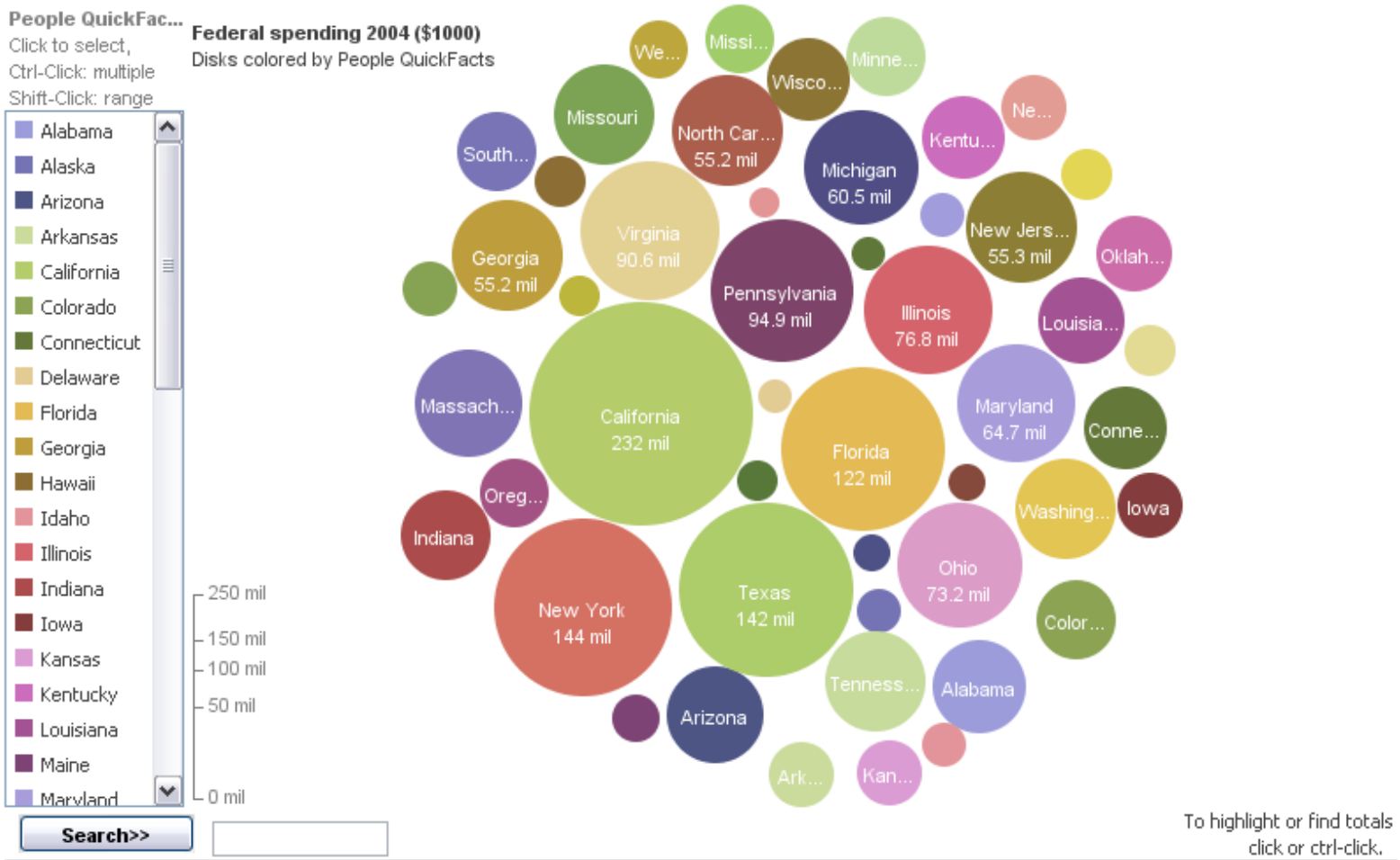
Block Histogram

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



Search>>

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 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 AIBERTO (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

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-Seal
- # 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:

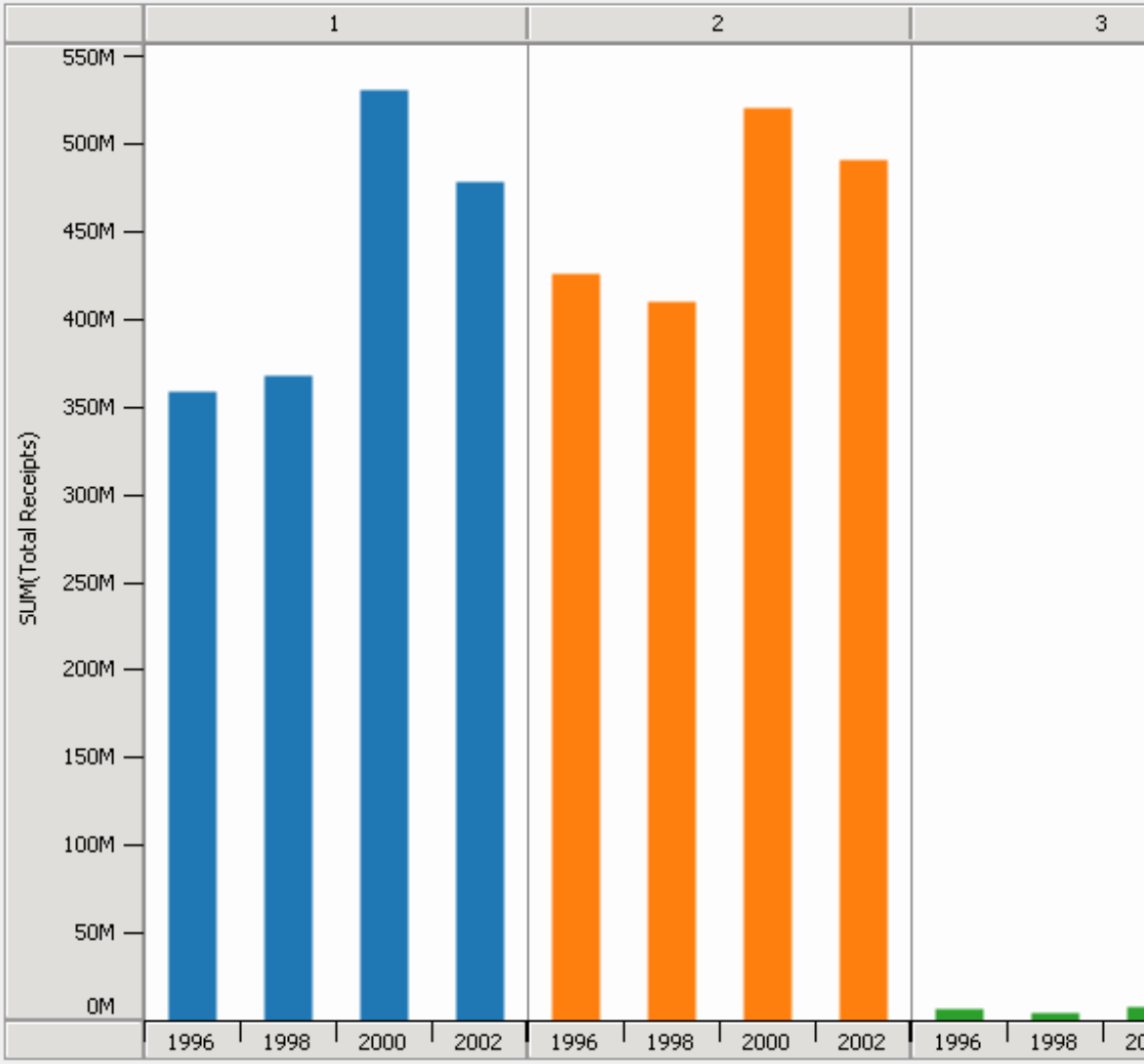
Legend:

1
2
3

Size:

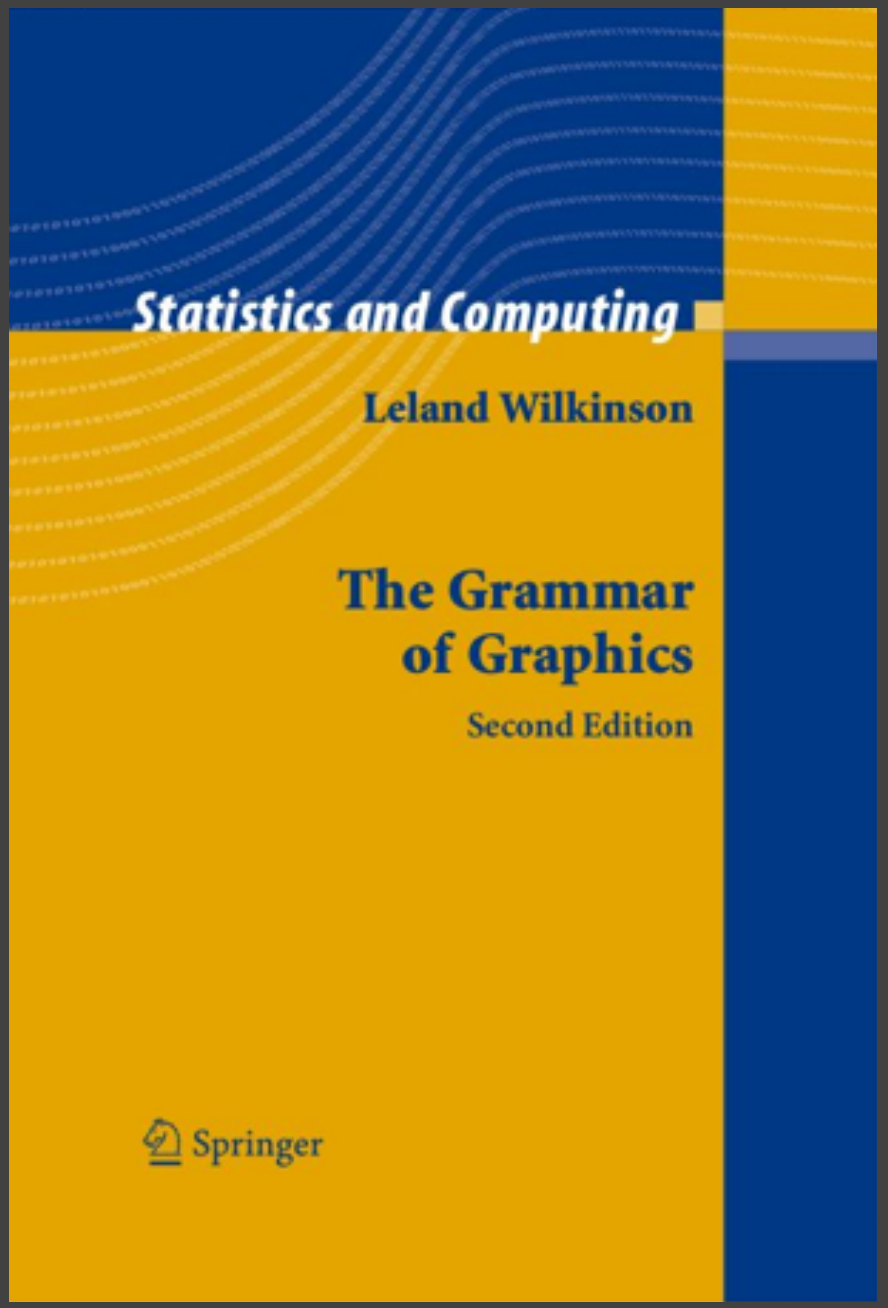
Columns: Party | Year

Rows: SUM(Total..

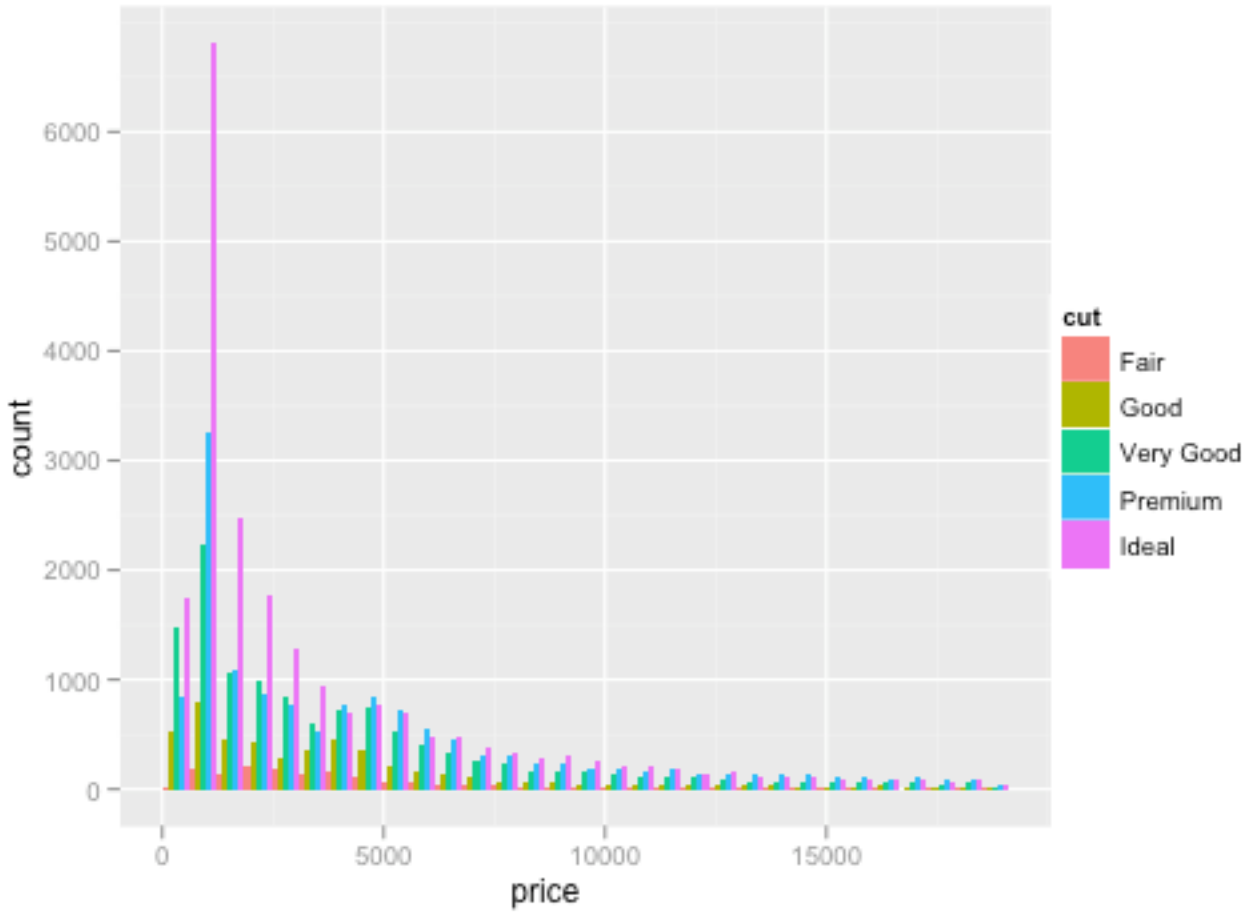


Sheet 1

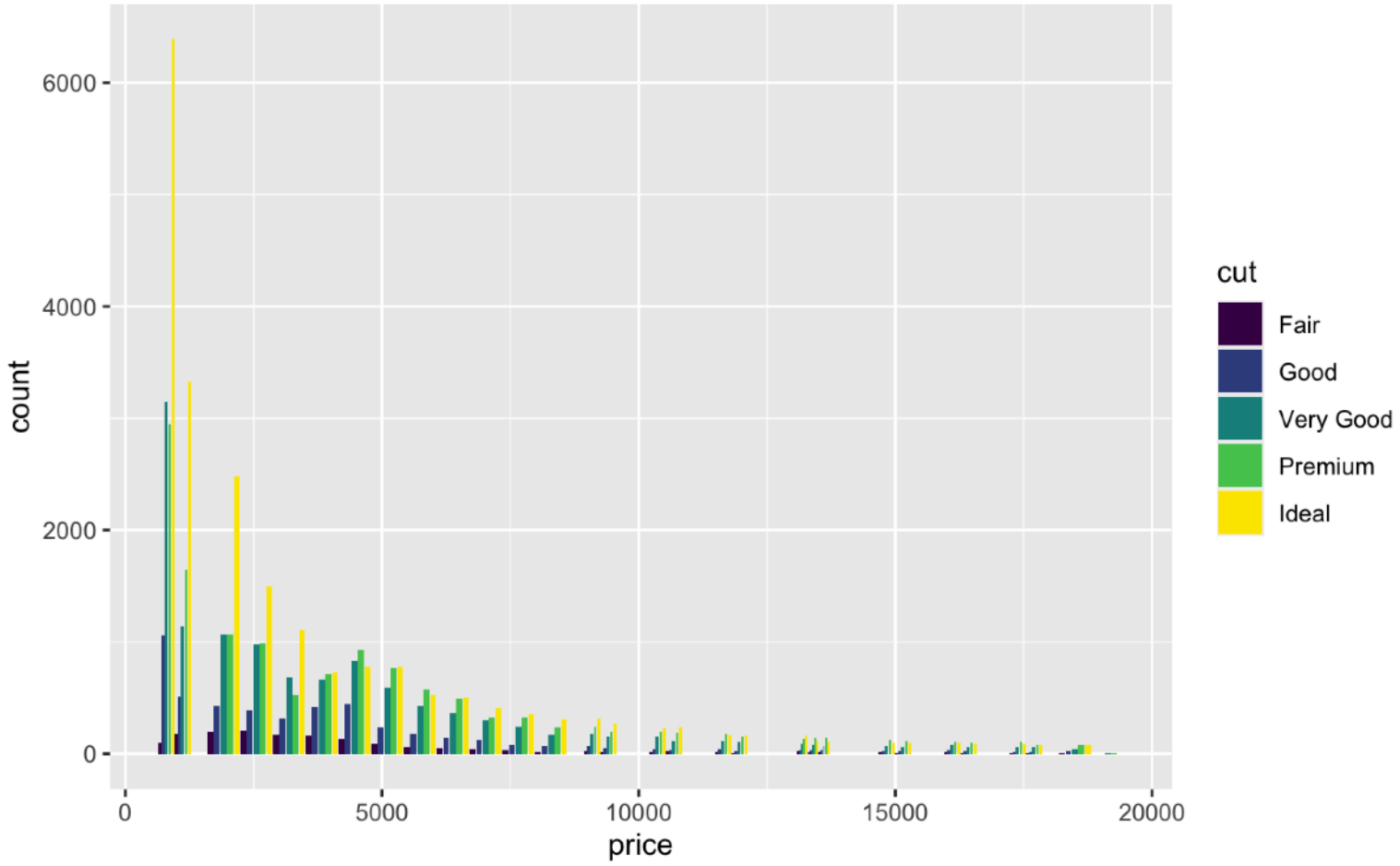
Ready


Statistics and Computing
Leland Wilkinson
The Grammar of Graphics
Second Edition
Springer

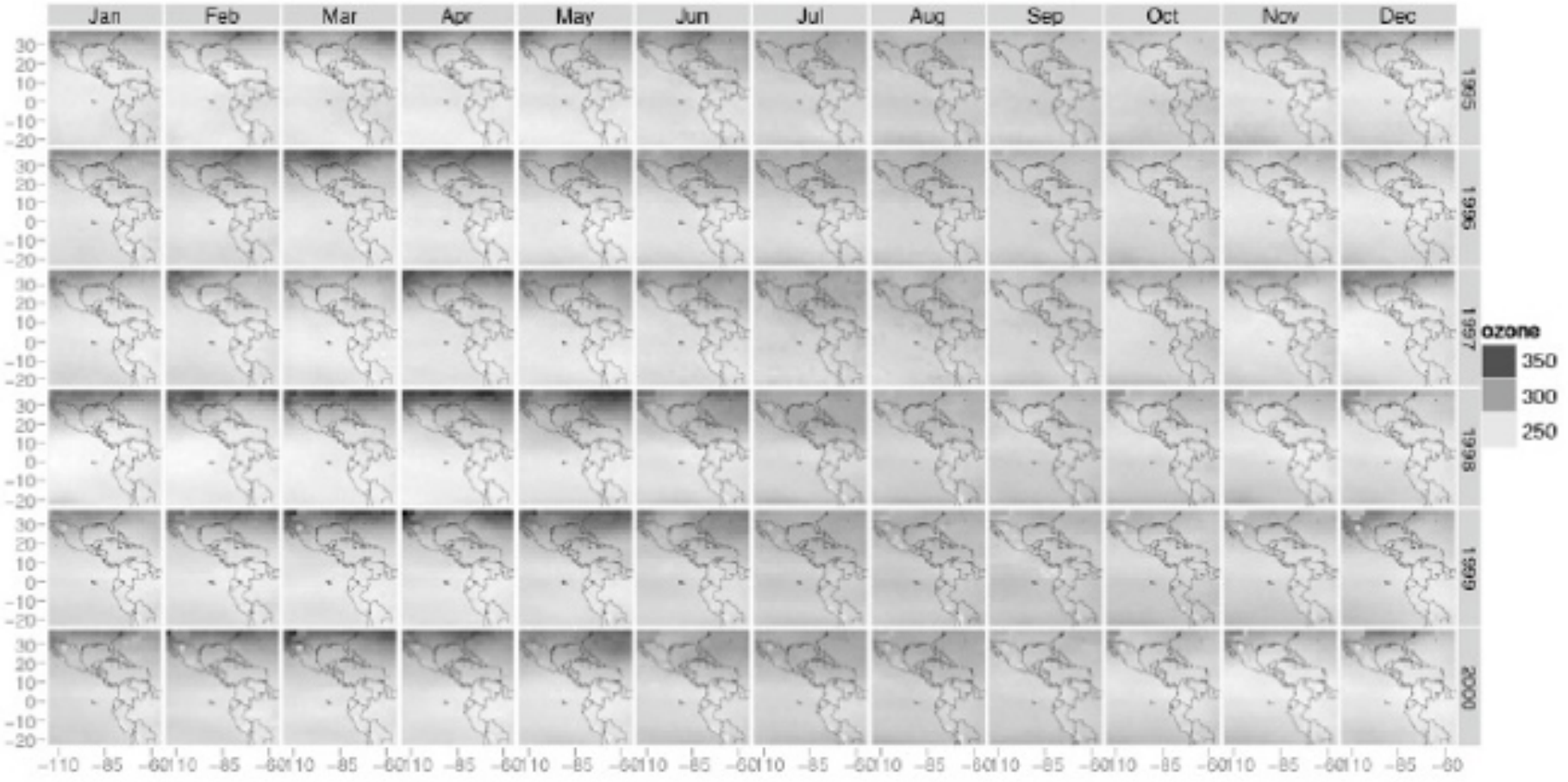
```
ggplot(diamonds, aes(x=price, fill=cut))
+ geom_bar(position="dodge")
```




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




```
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
```

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Graphics APIs

Processing, OpenGL, Java2D

Chart Typologies

Excel, Many Eyes, Google Charts

Visual Analysis Grammars

VizQL, ggplot2

?

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Protovis, D3.js

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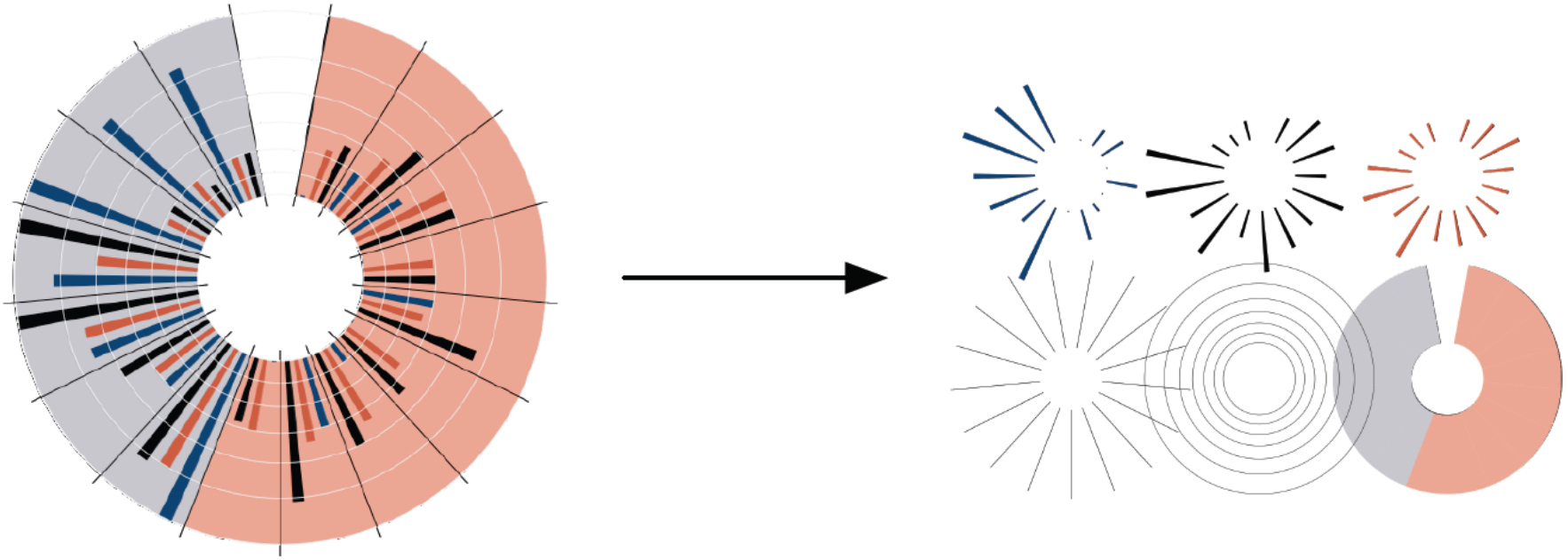
Protovis & D3

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**.

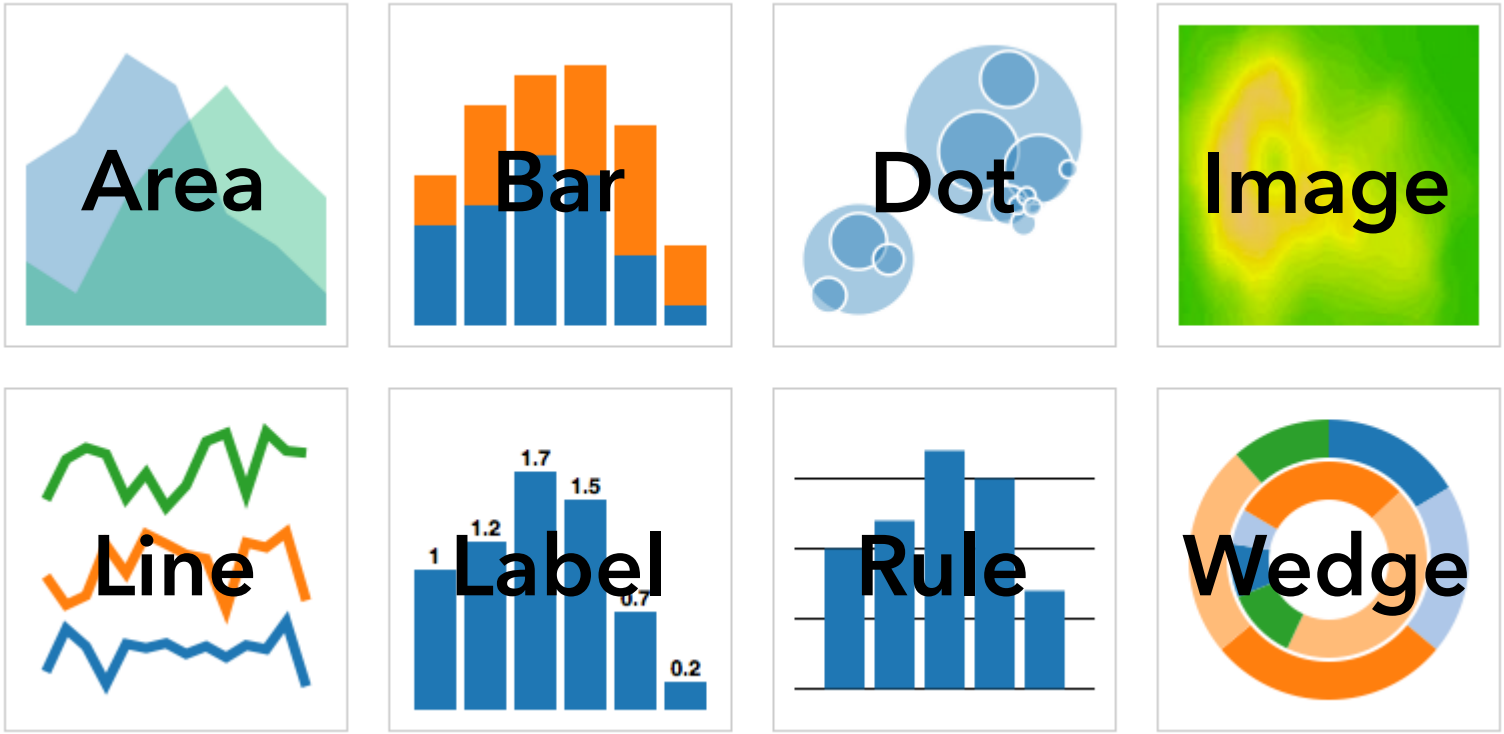
J. W. Tukey, M. B. Wilk
Data Analysis & Statistics, 1965

Protovis: A Grammar for Visualization



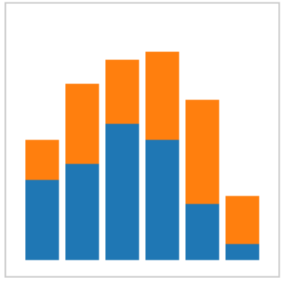
A graphic is a composition of data-representative marks.

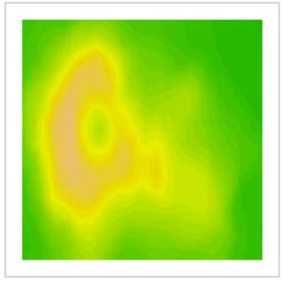
with **Mike Bostock** & **Vadim Ogievetsky**



MARKS: Protovis graphical primitives

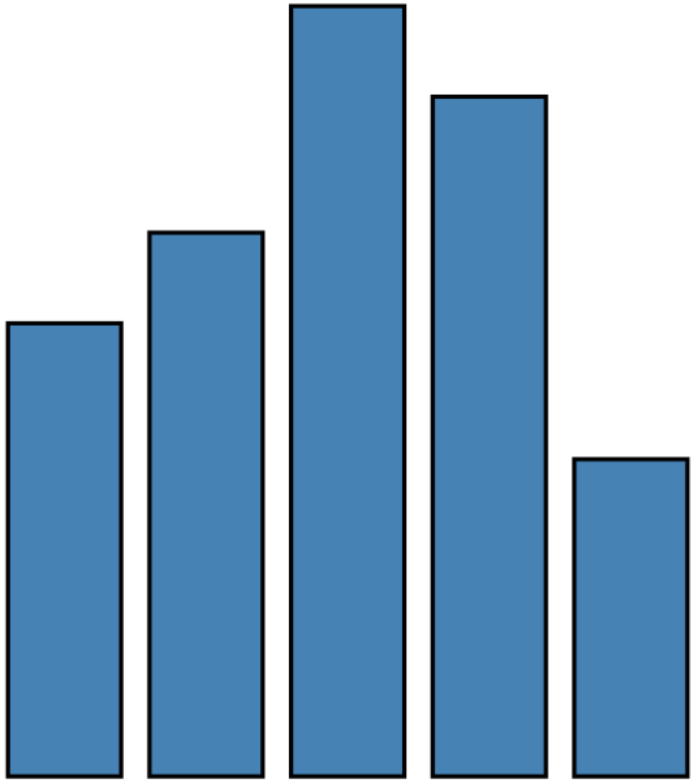
MARK	$\lambda : D \rightarrow R$
data	λ
visible	λ
left	λ
bottom	λ
width	λ
height	λ
fillStyle	λ
strokeStyle	λ
lineWidth	λ
...	λ



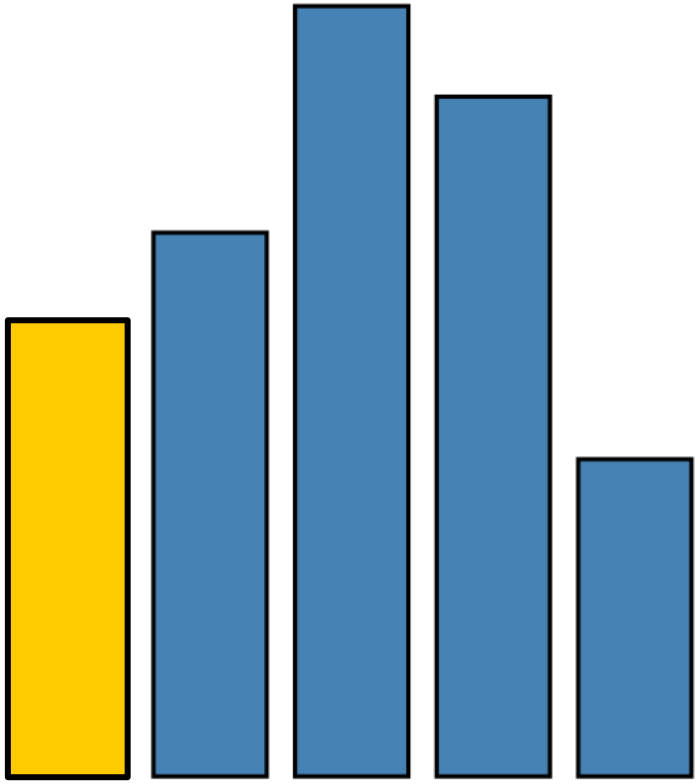
RECT $\lambda : D \rightarrow R$

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				
...	...				



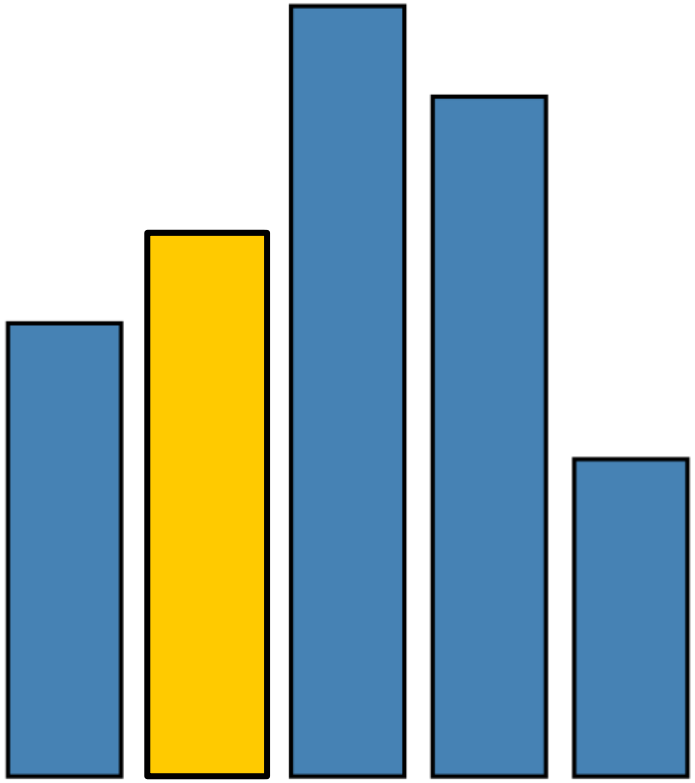
RECT $\lambda : D \rightarrow R$

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				
...	...				



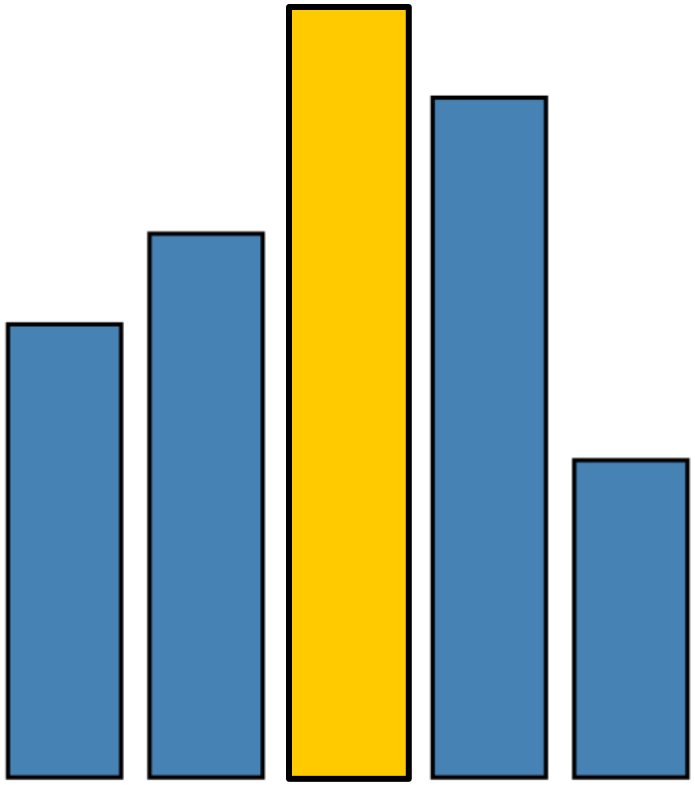
RECT $\lambda : D \rightarrow R$

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				
...	...				



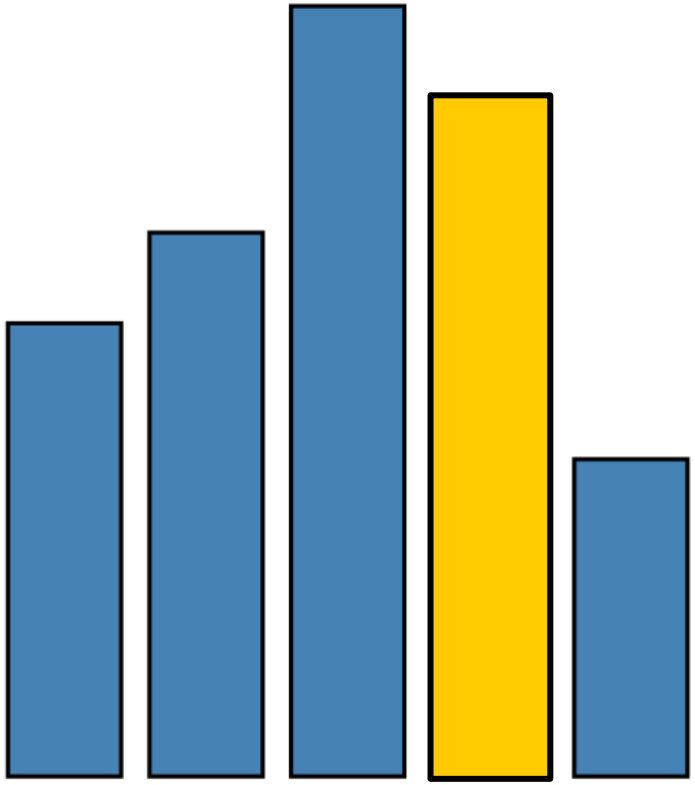
RECT $\lambda : D \rightarrow R$

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				
...	...				



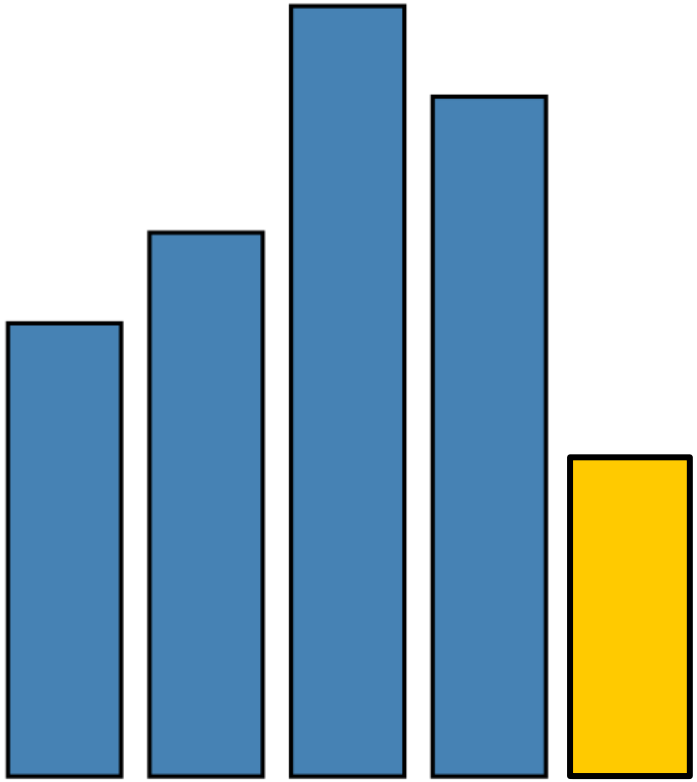
RECT $\lambda : D \rightarrow R$

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				
...	...				



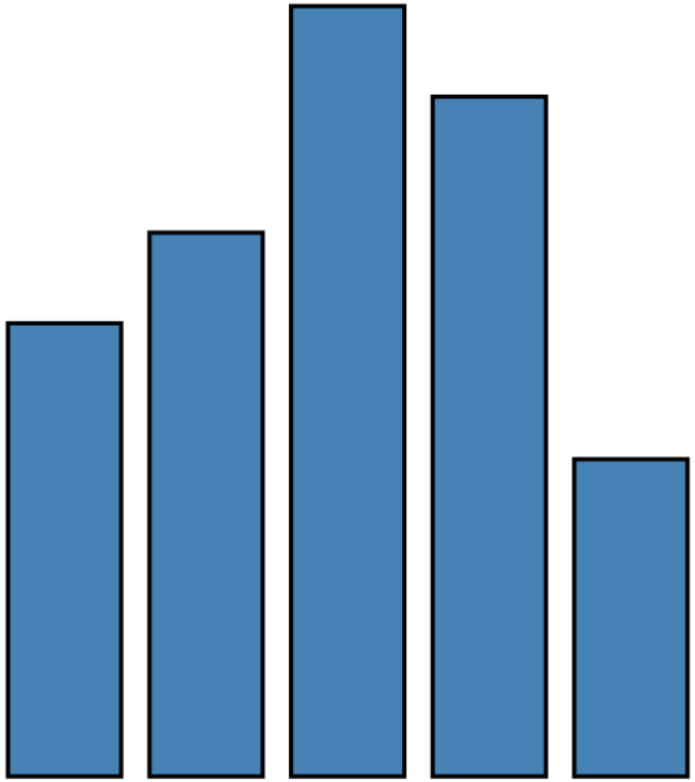
RECT $\lambda : D \rightarrow R$

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				
...	...				

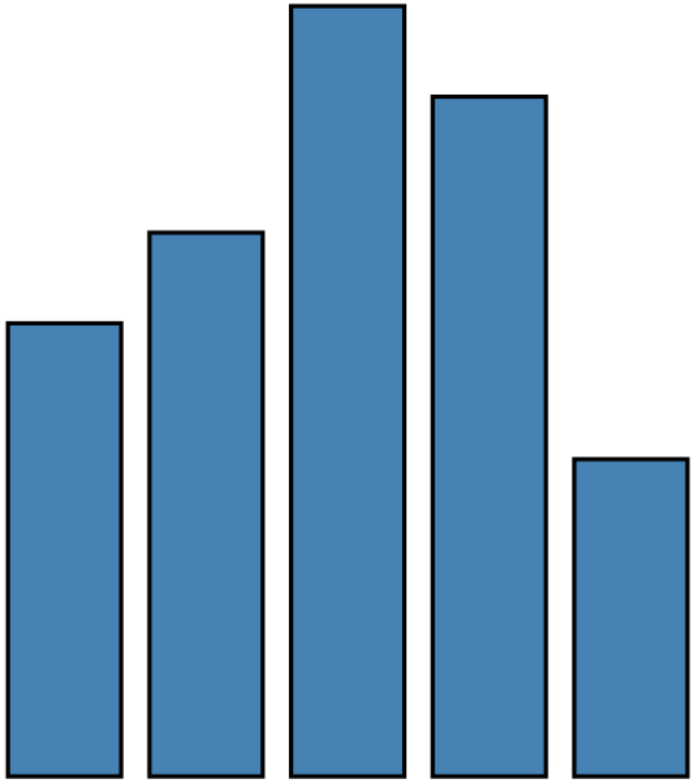


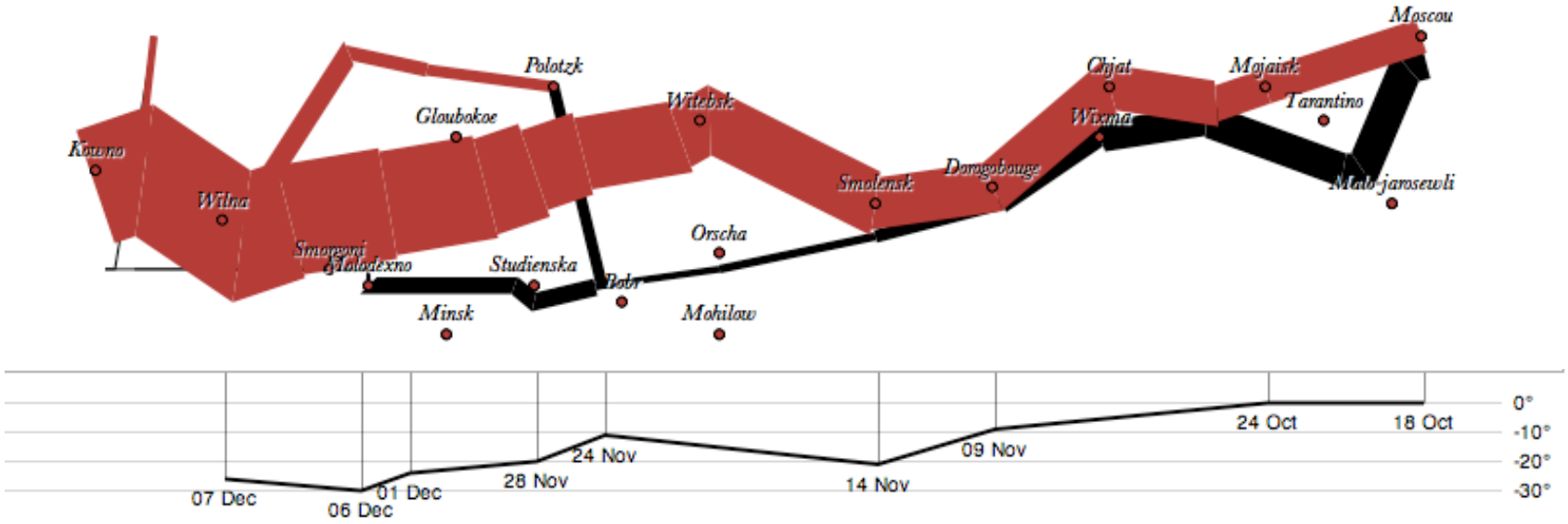
RECT $\lambda : D \rightarrow R$

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				
...	...				



```
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();
```





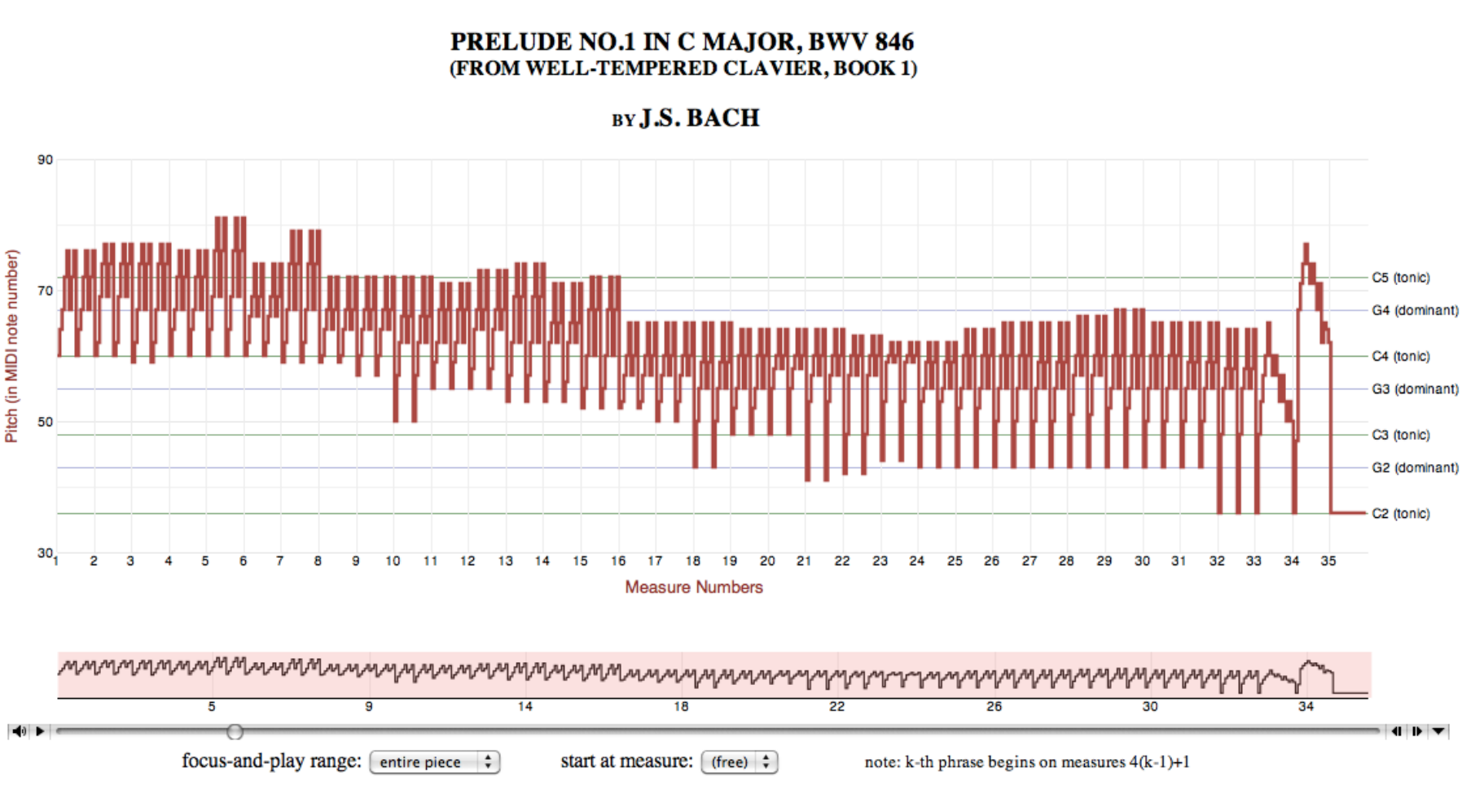

```
var army = pv.nest(napoleon.army, "dir", "group");
var vis = new pv.Panel();

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[panelIndex][0].dir]);

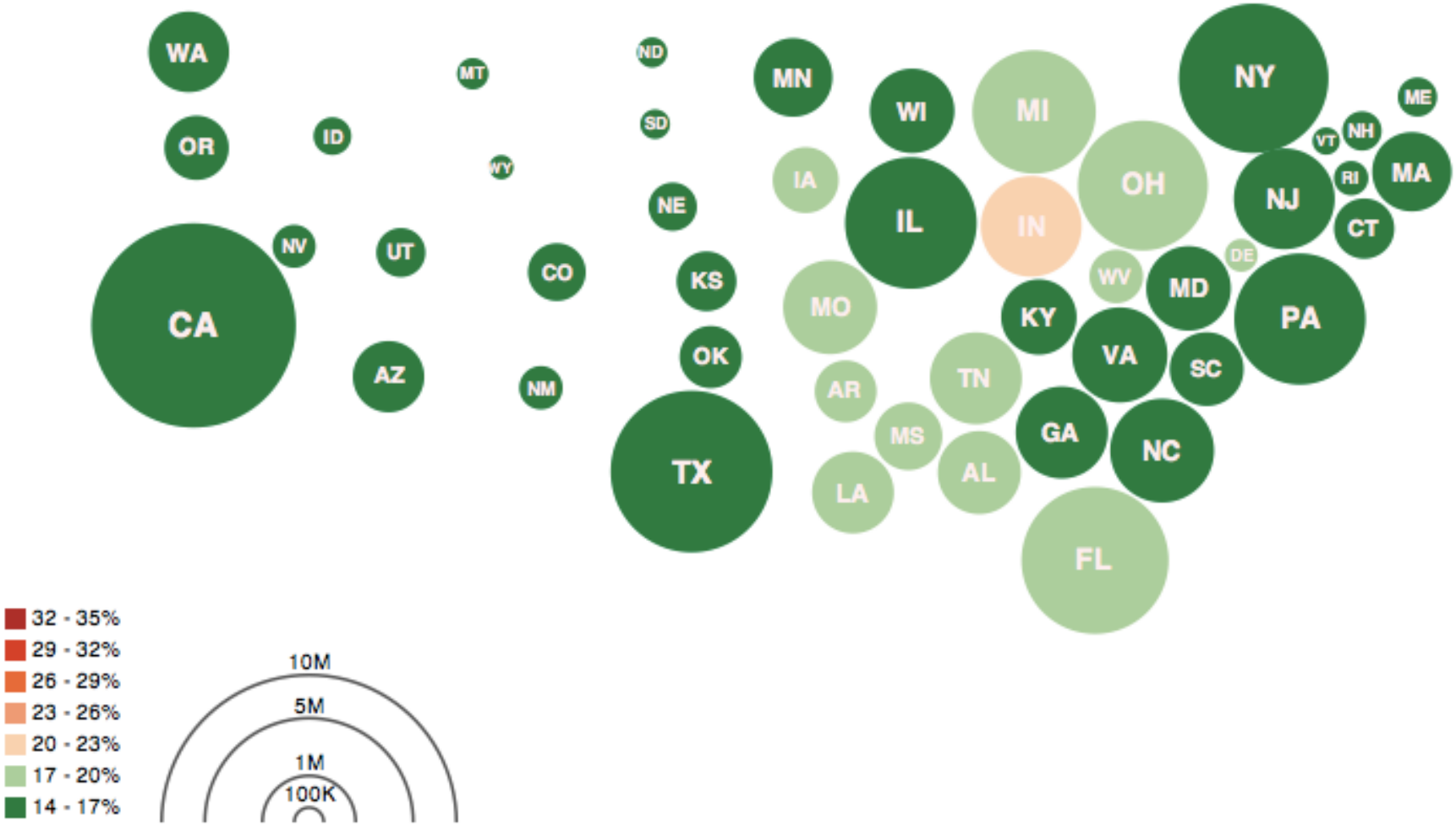
vis.add(pv.Label).data(napoleon.cities)
  .left(lon).top(lat)
  .text((d) => d.city).font("italic 10px Georgia")
  .textAlign("center").textBaseline("middle");
```

```
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");

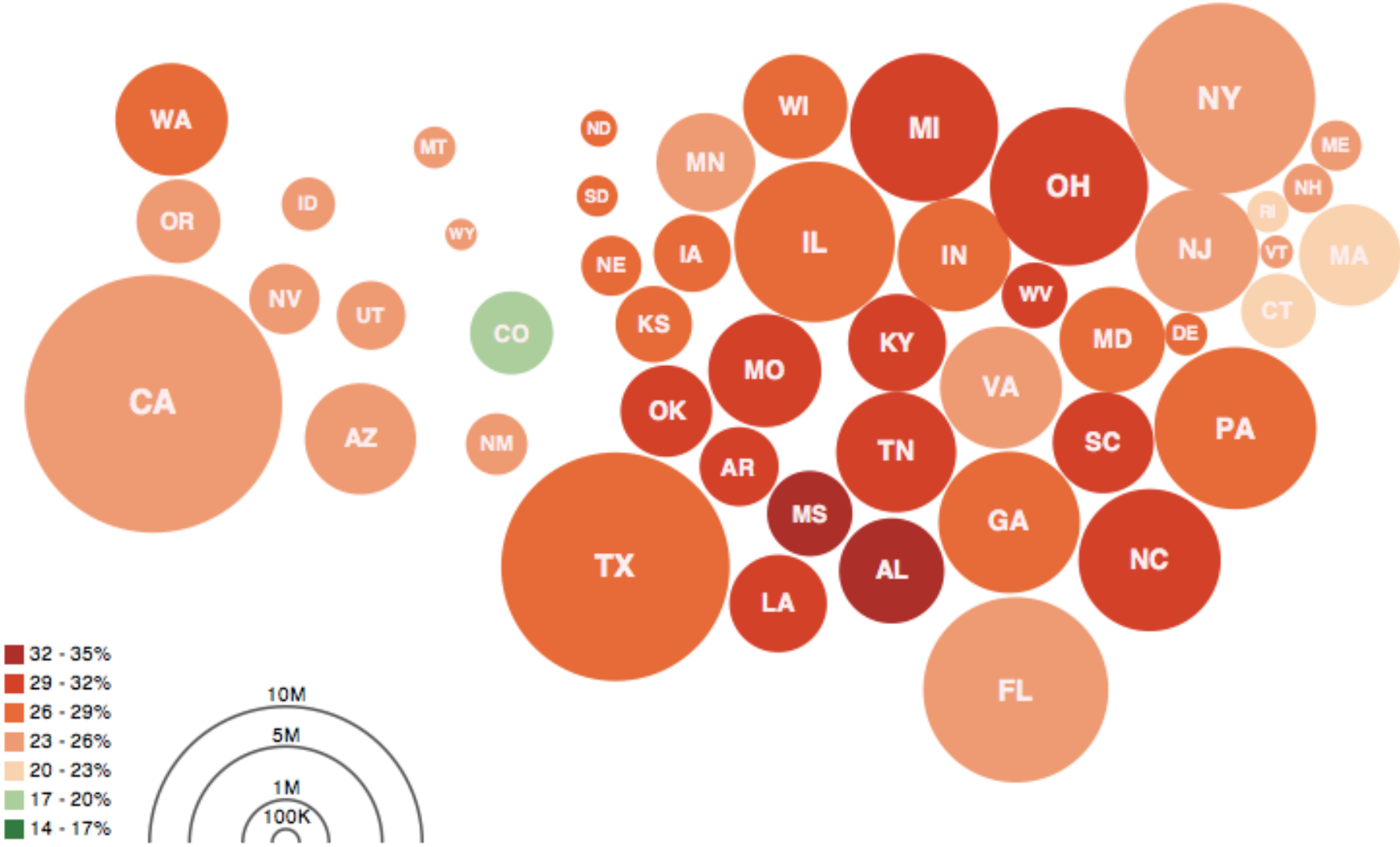
vis.add(pv.Line).data(napoleon.temp)
  .left(lon).top(tmp) .strokeStyle("#0")
 .add(pv.Label)
  .top((d) => 5 + tmp(d))
  .text((d) => d.temp+"° "+d.date.substr(0,6))
  .textBaseline("top").font("italic 10px Georgia");
```



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



Obesity Map | Vadim Ogievetsky



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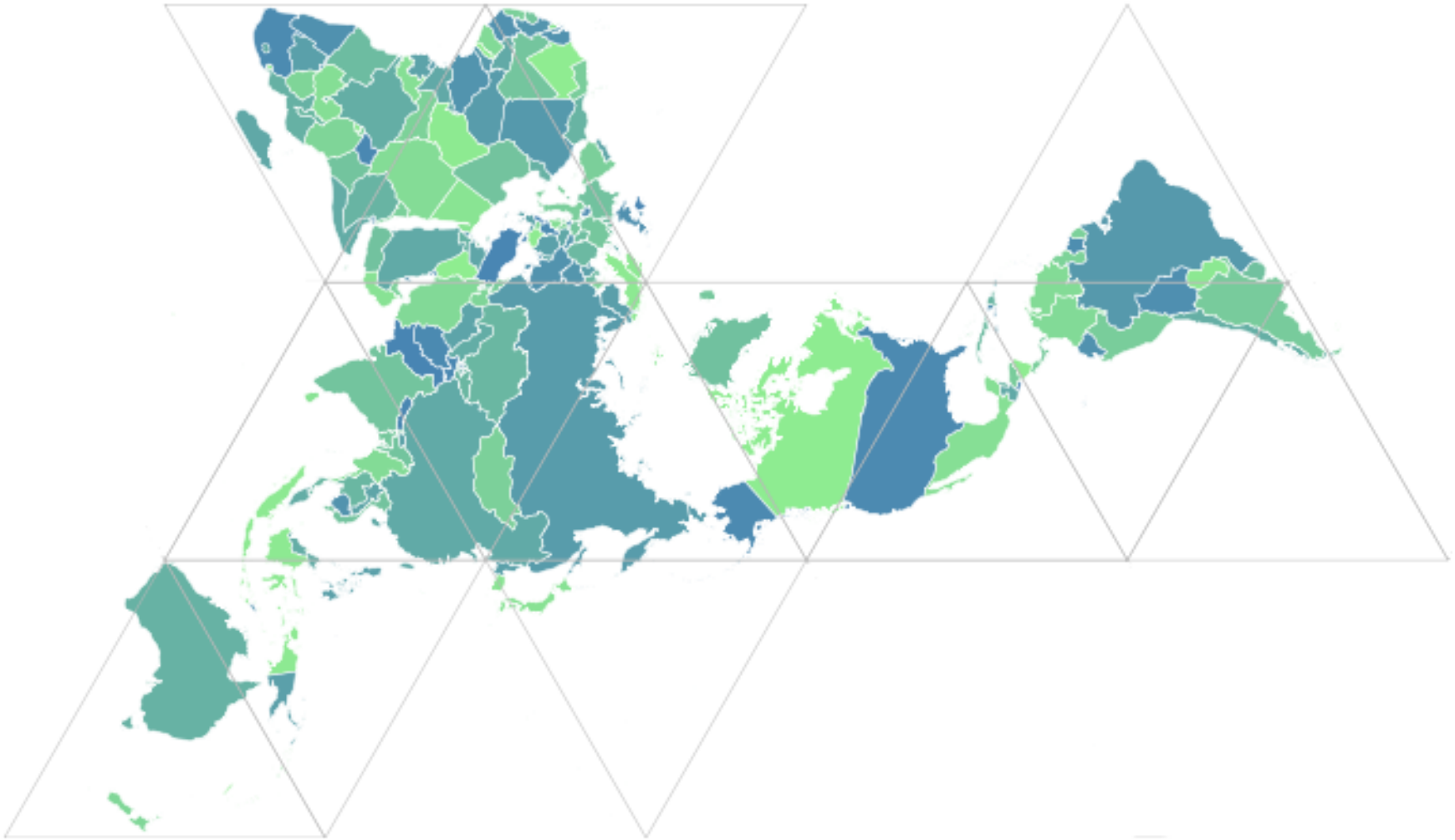
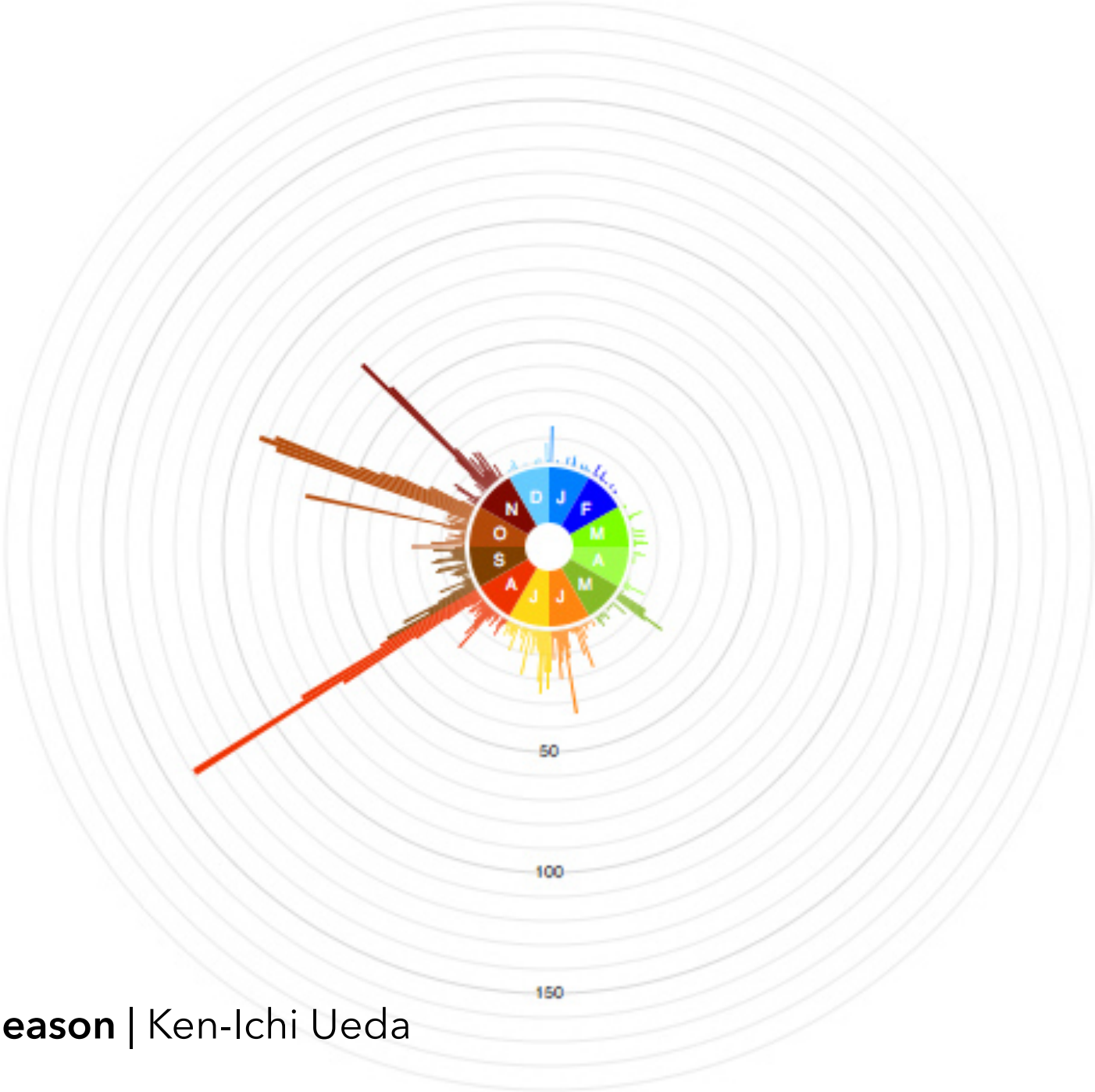
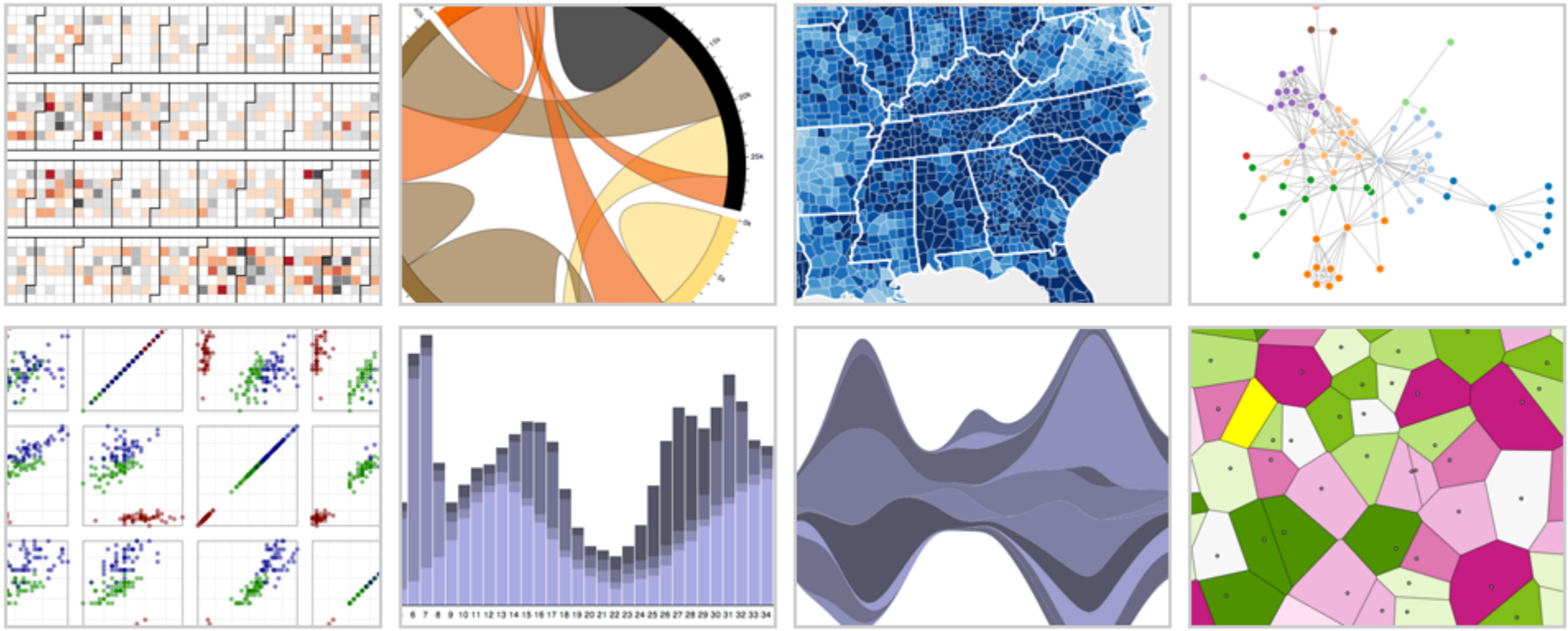


Dymaxion Maps | Vadim Ogievetsky



FlickrSeason | Ken-Ichi Ueda

d3.js Data-Driven Documents



with **Mike Bostock**, Jason Davies & 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

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+ 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***.

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```
// Add and configure an SVG element (<svg width="500" height="300">)
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
```

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```
// Add and configure an SVG element (<svg width="500" height="300">)
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
```

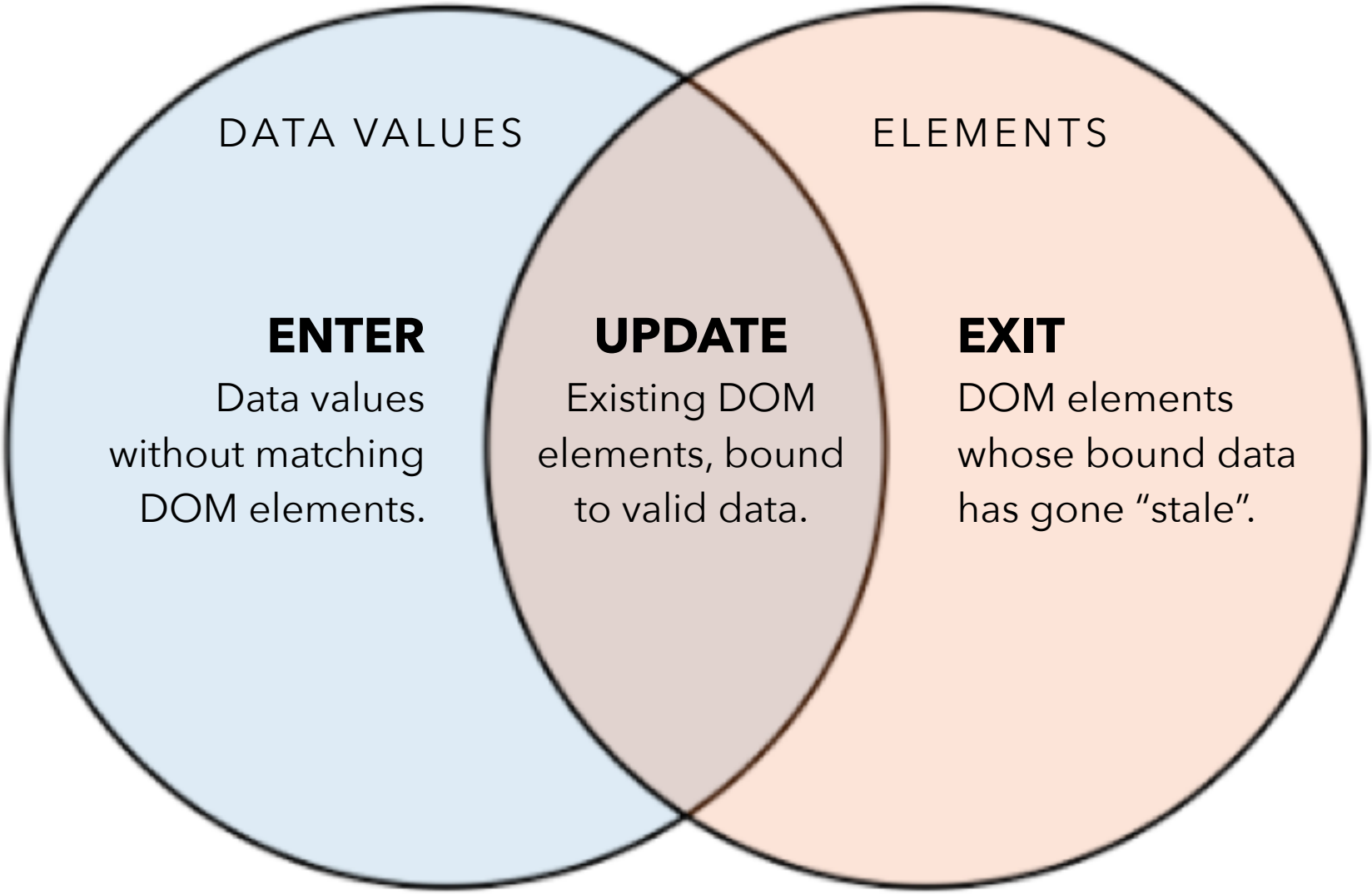
Data Binding

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);
```

The Data Join



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)
    .join(
        enter => enter.append("rect"), // create new
        update => update,              // update current
        exit => exit.remove()          // remove outdated
    )
```

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!

Chart Typologies

Excel, Many Eyes, Google Charts

Visual Analysis Grammars

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Administrivia

A2: Exploratory Data Analysis

Use visualization software to form & answer que[illegible]s

First steps:

Step 1: Pick domain & data

Step 2: Pose questions

Step 3: Profile the da[illegible]

Iterate as needed

Cre[illegible]at[illegible]

Inte[illegible]with d[illegible]

Refin[illegible]r q[illegible]ons

Autho[illegible]ort

Screens[illegible]ots of most insightful views *(8+)*

Include titles and captions for each view

DONE

Due by 11:59pm

Monday, Oct 26

Tutorials

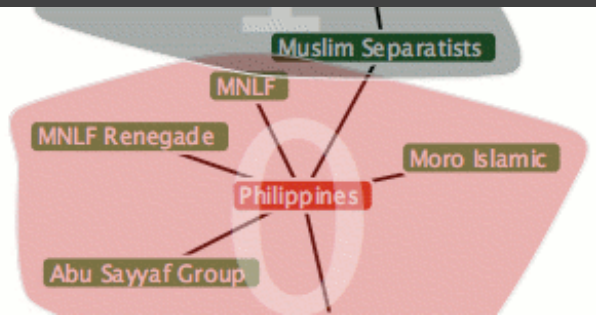
D3.js Deep Dive
In Class - Thursday, Oct. 29
Led by Mick and Naveena

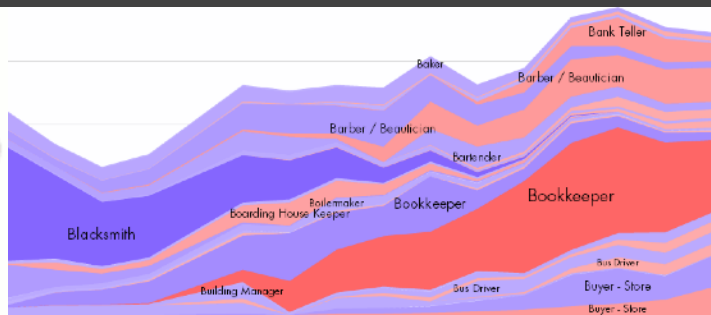
A3: Interactive Prototype

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, November 9**.

Work in project teams of 3-5 people.



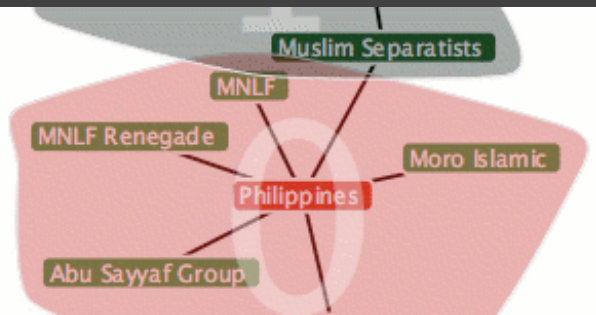


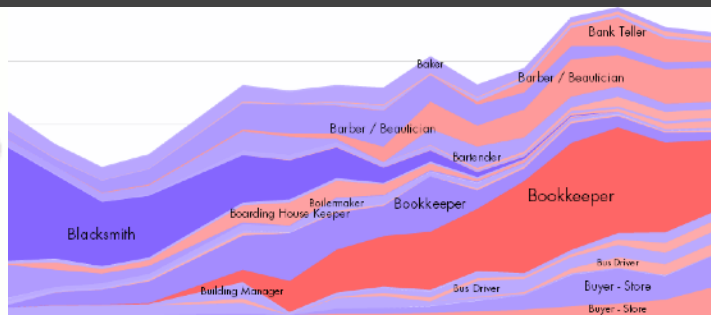
Requirements

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 visualization with GitHub pages or Observable.

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





A3 & Final Project Team

Form a **team of 3-5** for A3 and the Final Project.

Start thinking about your Final Project, too!

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

Submit signup form by **Friday 10/30, 11:59pm**.

If you do not have team mates, you should:
- Post on Ed about your interests/project ideas

Team Member Roles

We encourage you to structure team responsibilities!

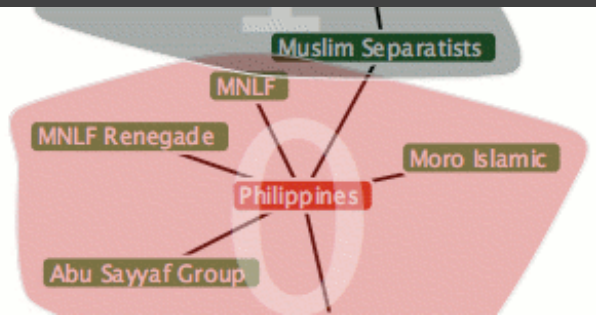
Coordinator: Organize meetings, track deadlines, *etc.*

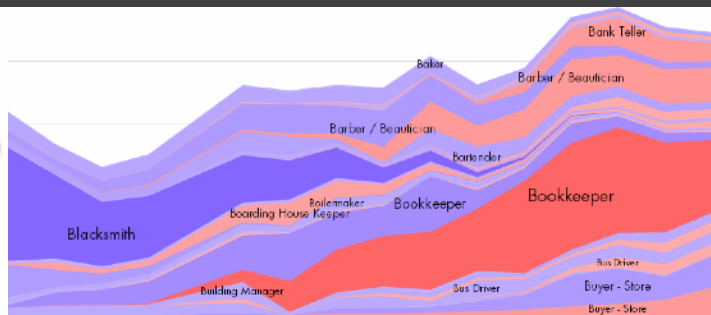
Data Lead: Data wrangling, management, distillation

Tech Lead: Manage code integration, GitHub repo

UX Lead: Visualization/interaction design & evaluation

One may have multiple roles, share work across roles…



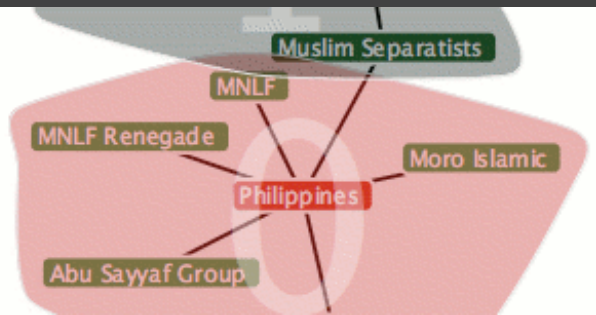


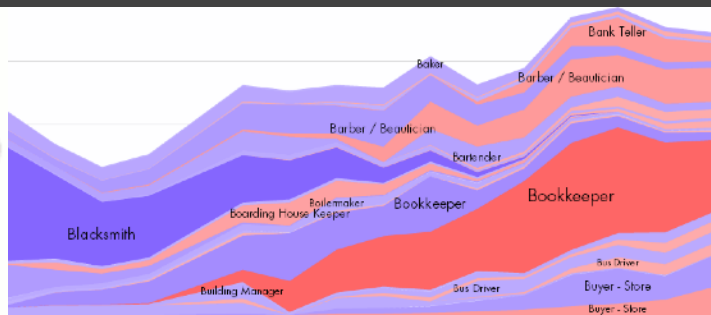
Interactive Prototype Tips

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

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Charting Tools

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Declarative Languages

Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

Programming Toolkits

What is a Declarative Language?

Programming by describing *what*, not *how*

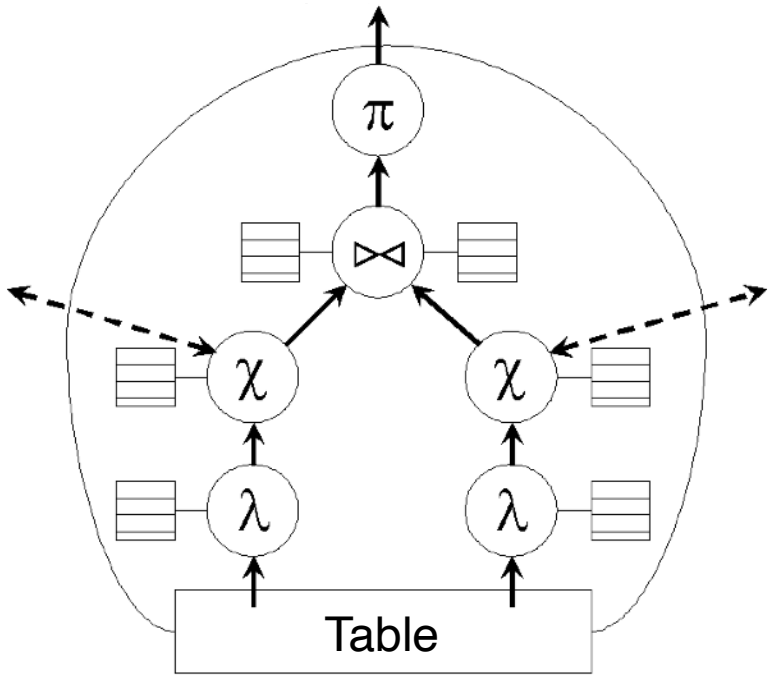
Separate **specification** (*what you want*) from **execution** (*how it should be computed*)

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

```
d3.selectAll("rect")
  .data(my_data)
 .join("rect")
  .attr("x", d => xscale(d.foo))
  .attr("y", d => yscale(d.bar))
```


```
<!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-8"></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




```
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?

Faster iteration, less code, larger user base?

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.

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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***

Visualization Grammars

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

Declarative Languages

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?!

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Interactive Data Exploration

Tableau, ***Lyra, Voyager***

Graphical Interfaces

Visual Analysis Grammars

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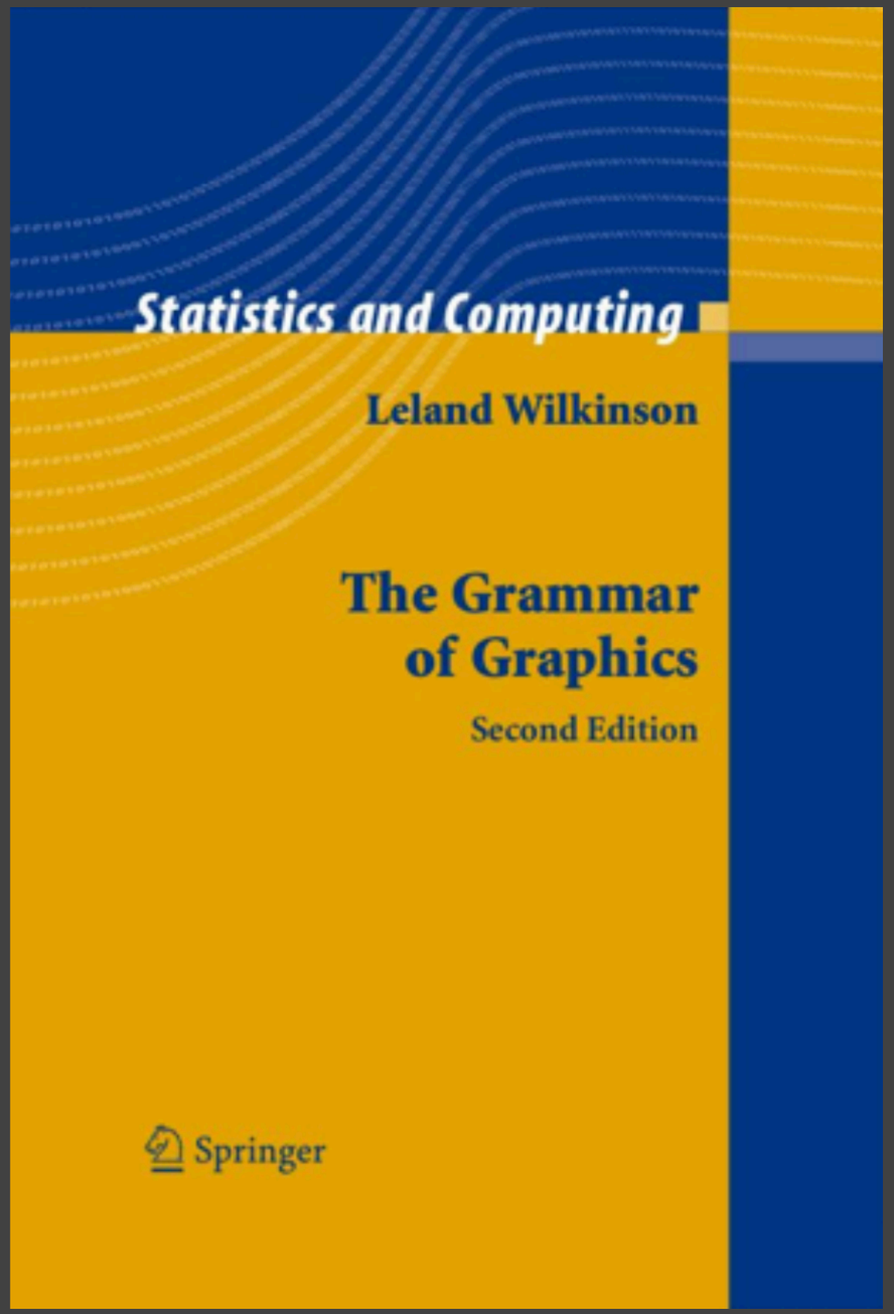
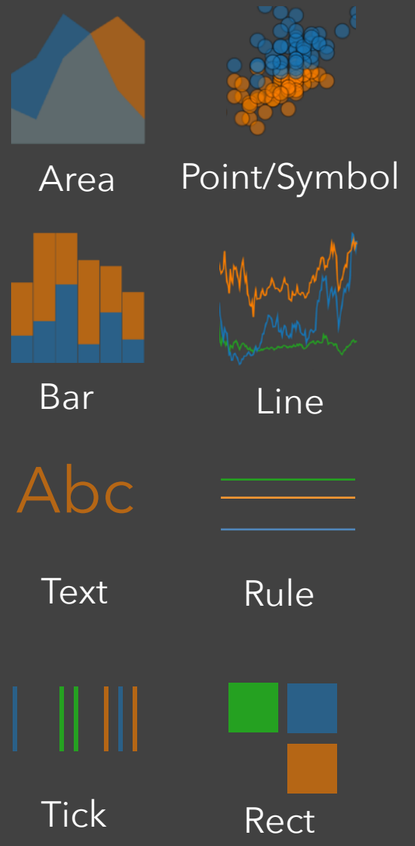
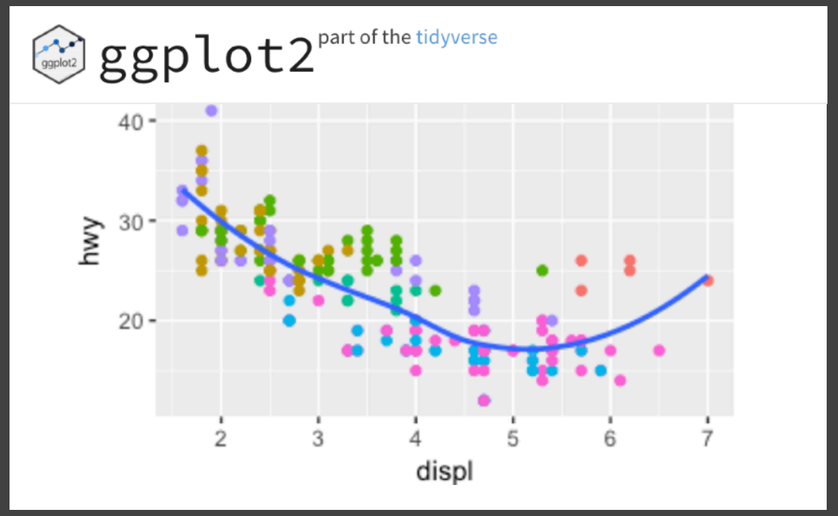

Statistics and Computing
Leland Wilkinson
The Grammar of Graphics
Second Edition
Springer

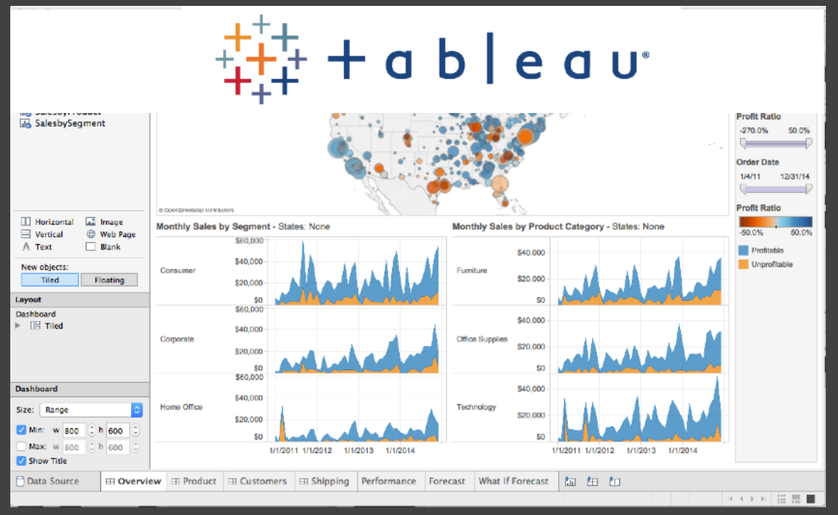
Some Grammar of Graphics “Building Blocks”

Data	Input data source to visualize.
Transform	Filter, aggregation, binning, etc.
Mark	Data-representative graphics.
Encoding	Mapping between data and mark properties.
Scale	Functions that map data values to visual values.
Guides	Axes & legends that visualize scales.



Tools Influenced by the Grammar of Graphics



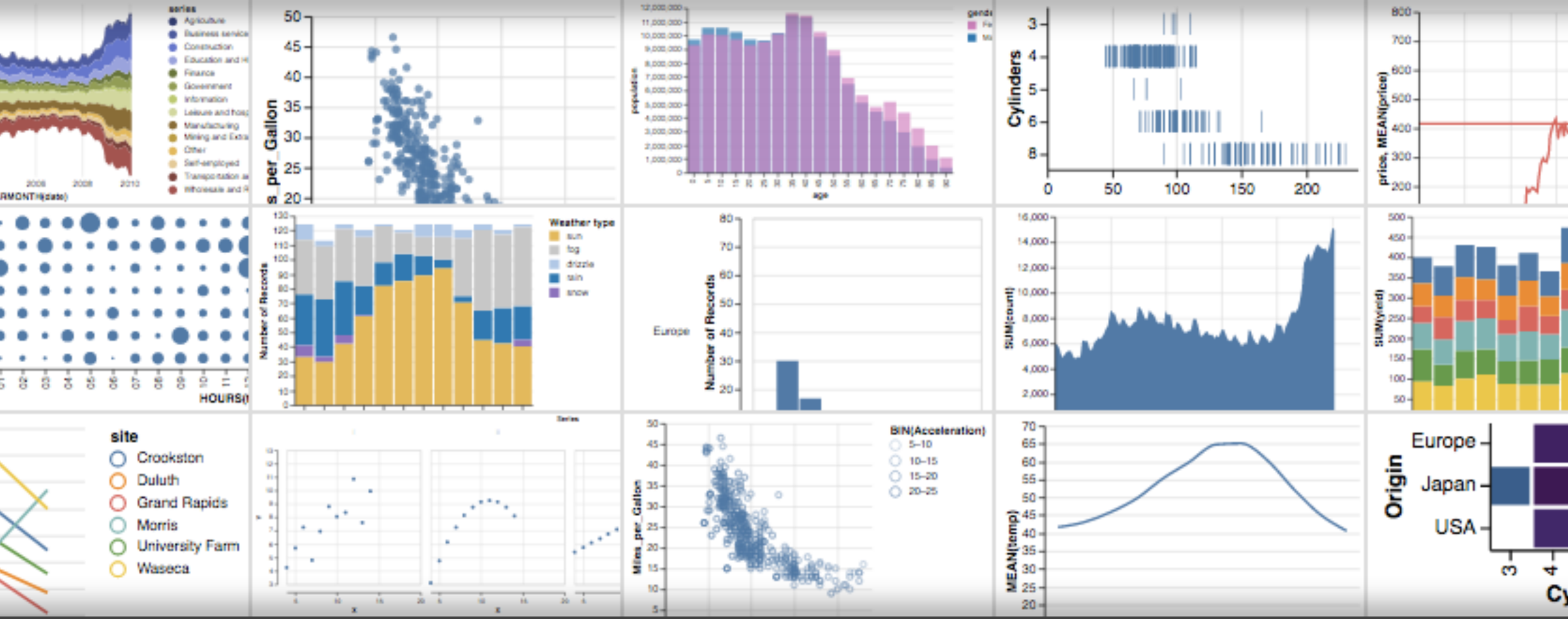


Facilitate **rapid exploration**
with **concise** specifications
by omitting low-level details.

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

But **limited** support for ***interaction*.**

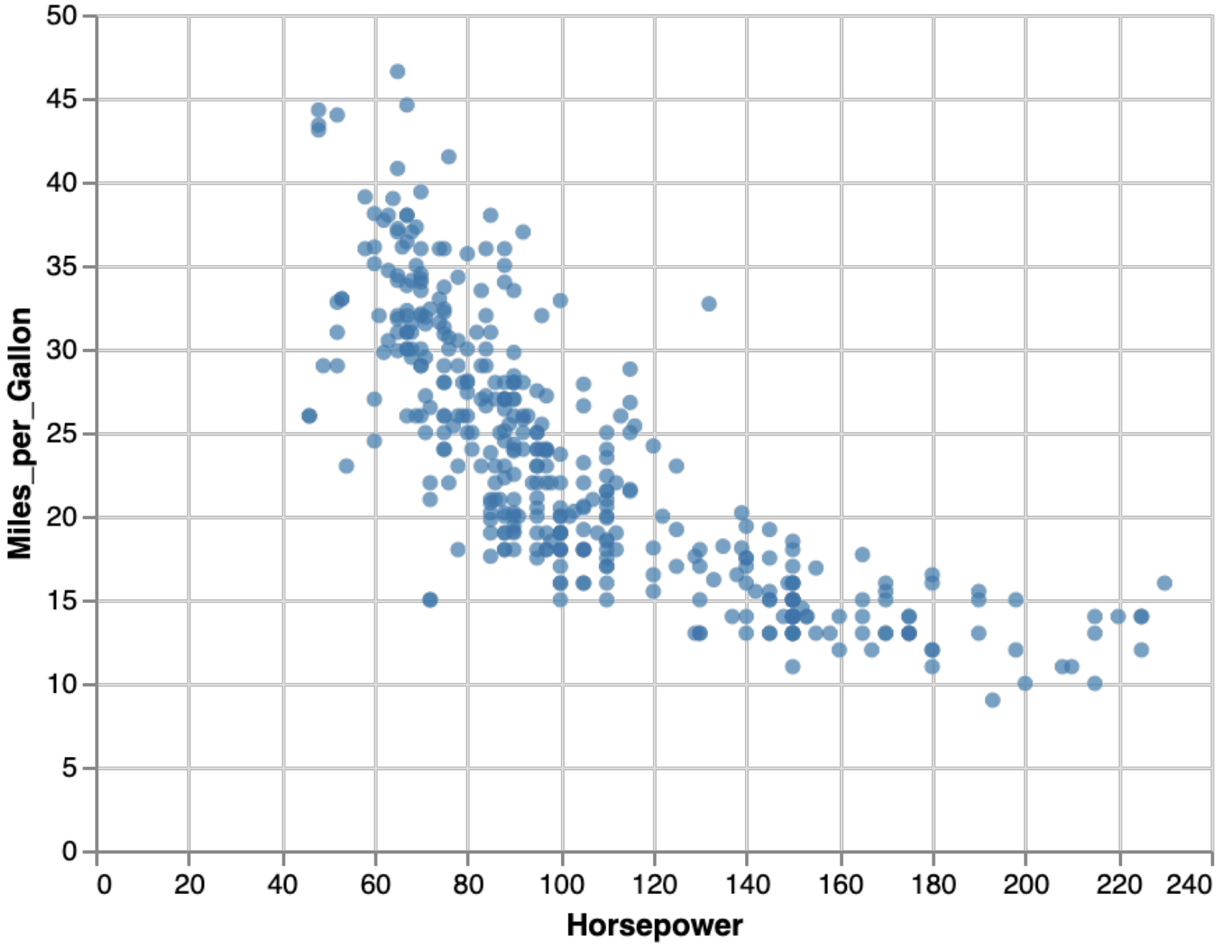
How might we author ***interactive*** **graphics** in the **midst of analysis**?



Vega-Lite: A Grammar of Interactive Graphics

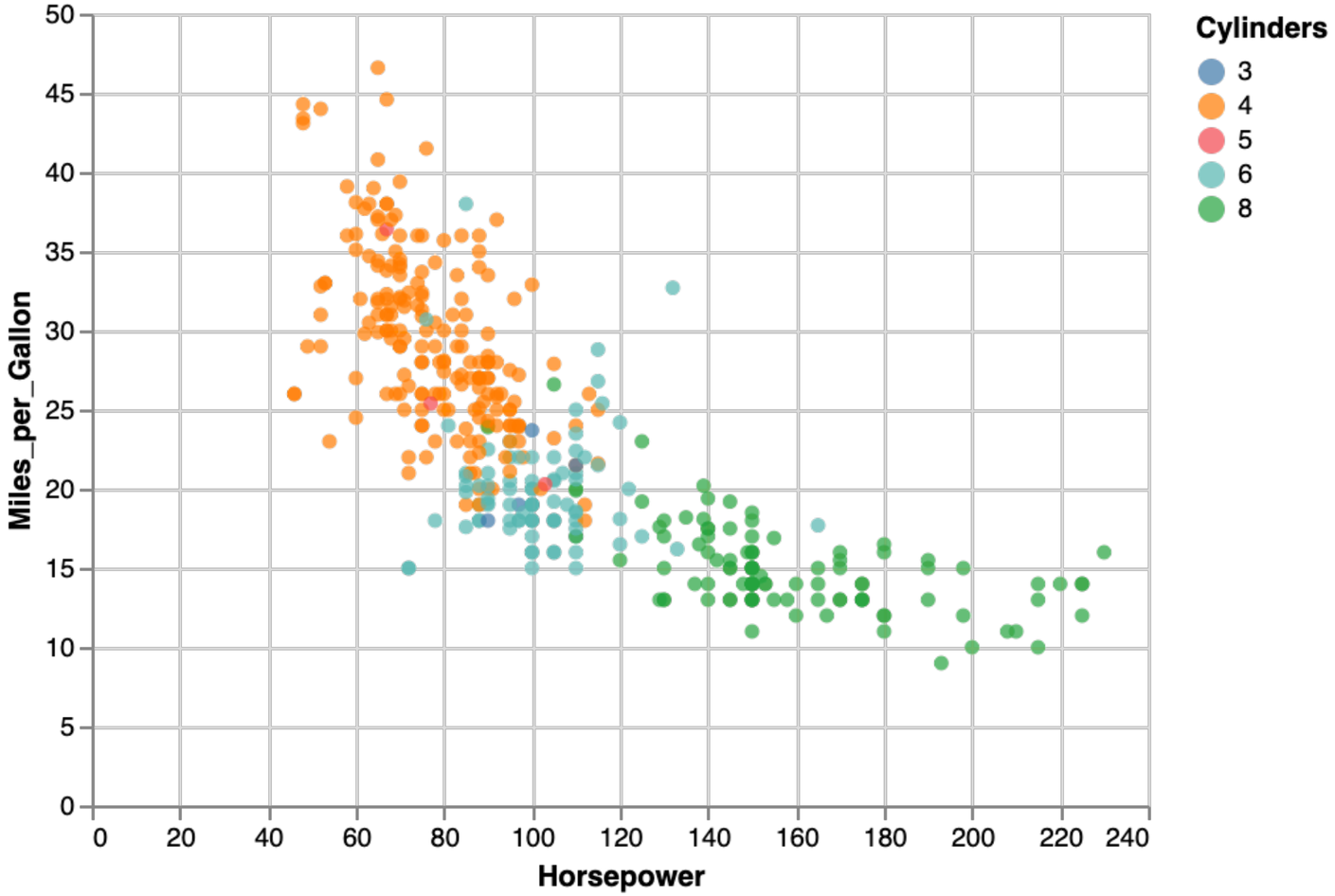
A. Satyanarayan, D. Moritz, K. Wongsuphasawat & J. Heer. *TVCG 2017*

Vega-Lite: Scatter Plot



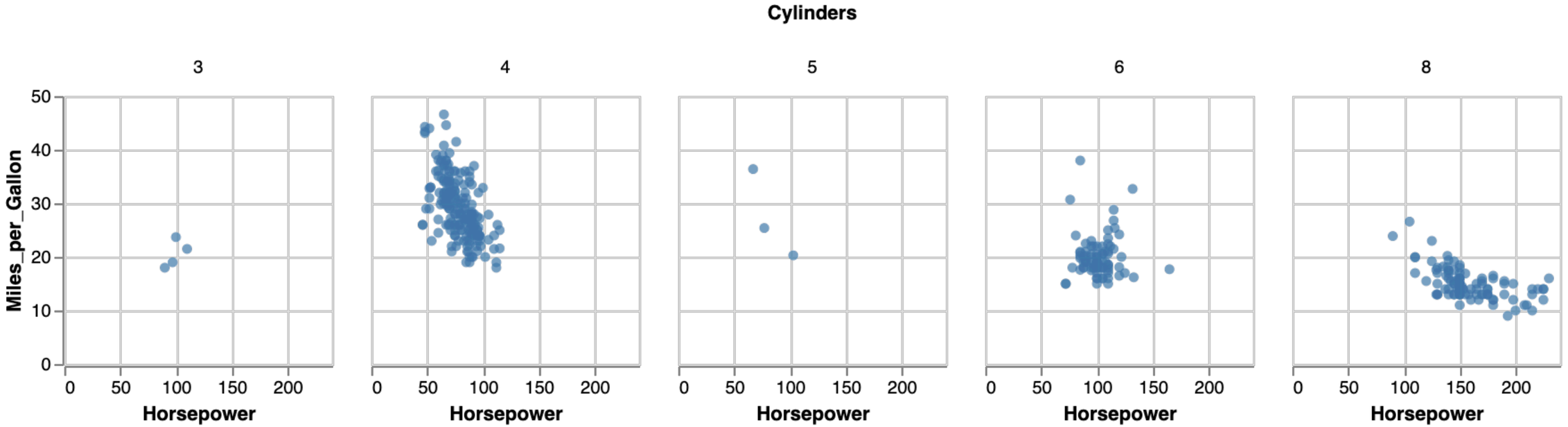

```
markCircle()
  .data('data/cars.json')
  .encode(
    x().fieldQ('Horsepower'),
    y().fieldQ('Miles_per_Gallon')
  )
```

Vega-Lite: Scatter Plot



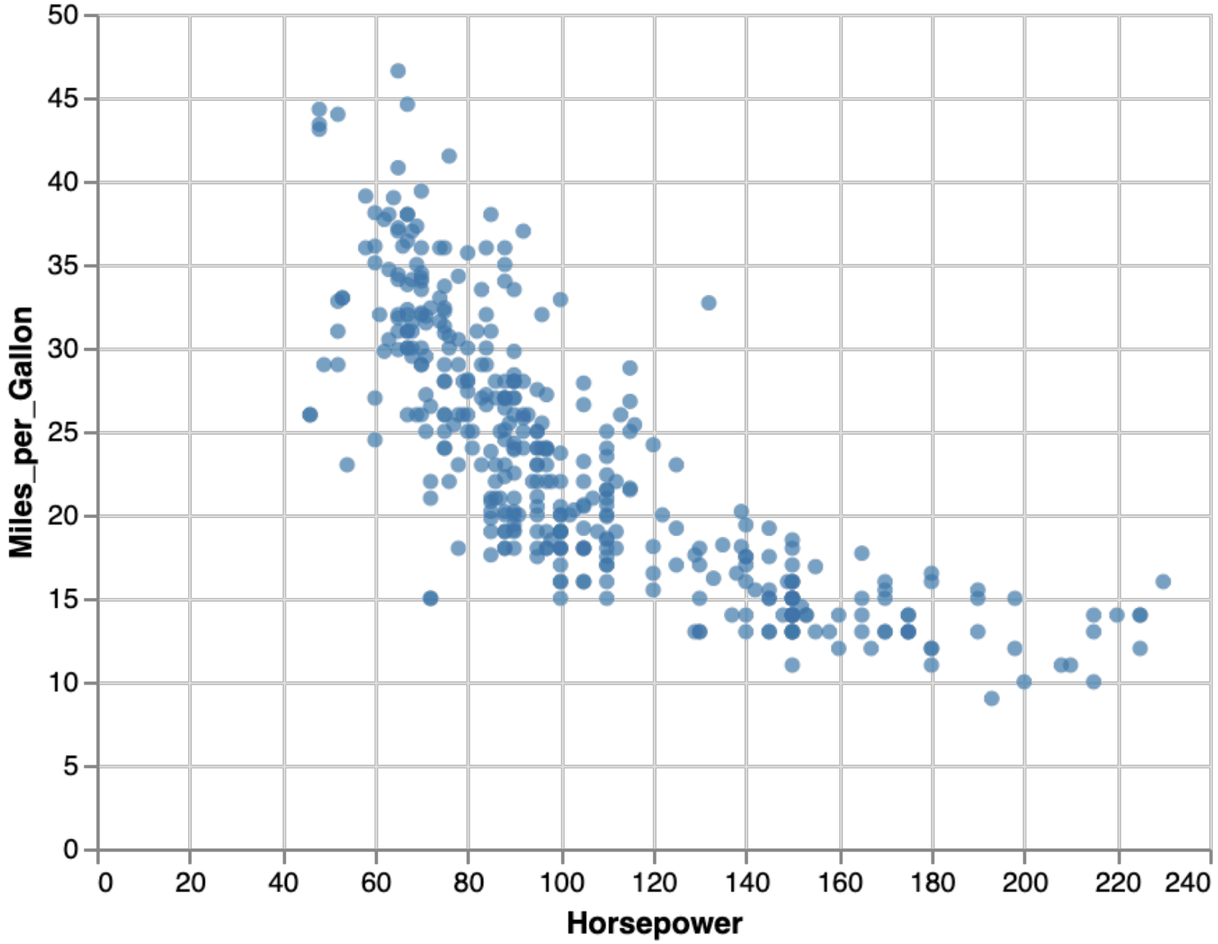

```
markCircle()
  .data('data/cars.json')
  .encode(
    x().fieldQ('Horsepower'),
    y().fieldQ('Miles_per_Gallon'),
    color().fieldN('Cylinders')
  )
```

Vega-Lite: Trellis Plot



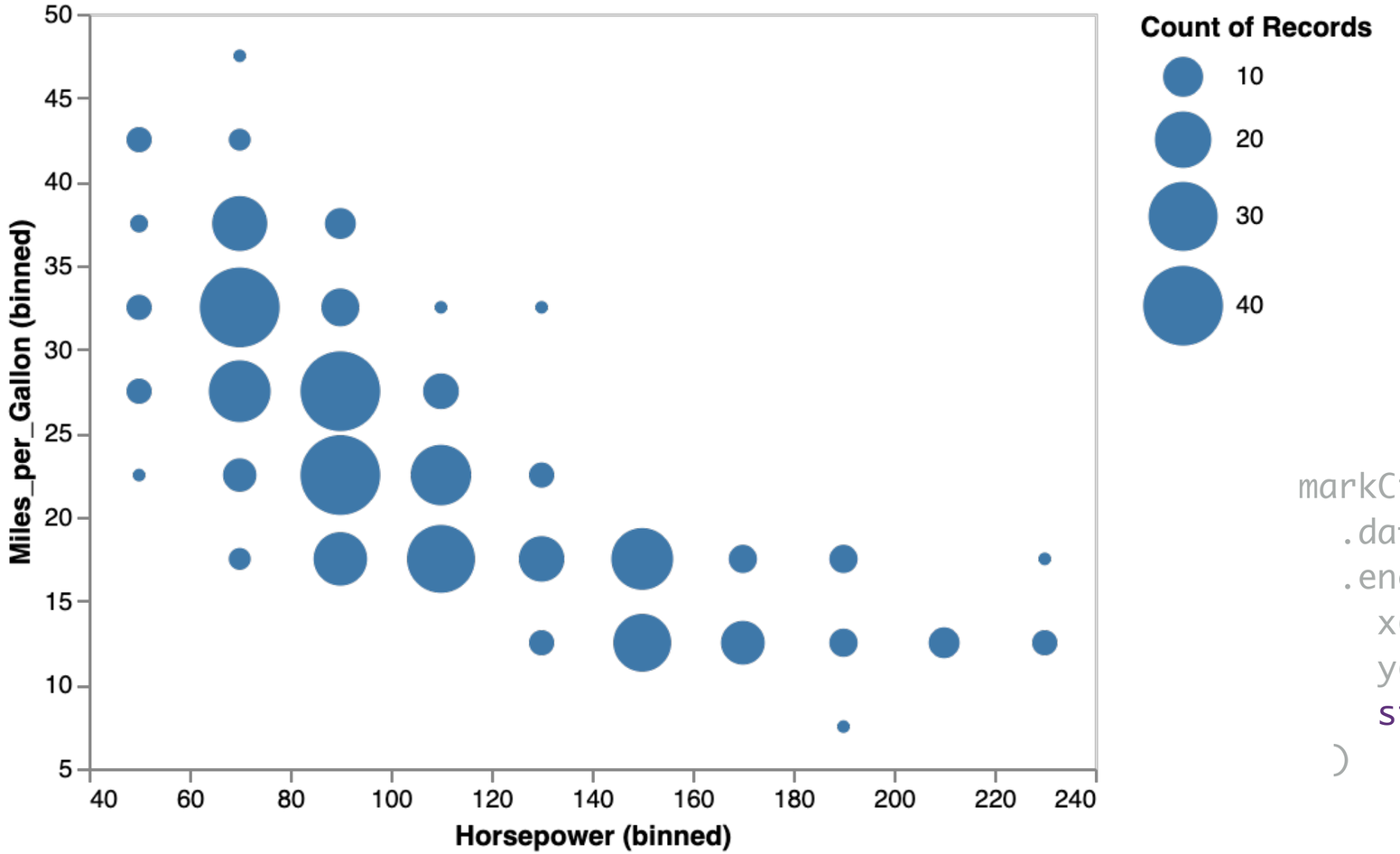

```
markCircle()
  .data('data/cars.json')
  .encode(
    x().fieldQ('Horsepower'),
    y().fieldQ('Miles_per_Gallon'),
    column().fieldN('Cylinders')
  )
```

Vega-Lite: Scatter Plot



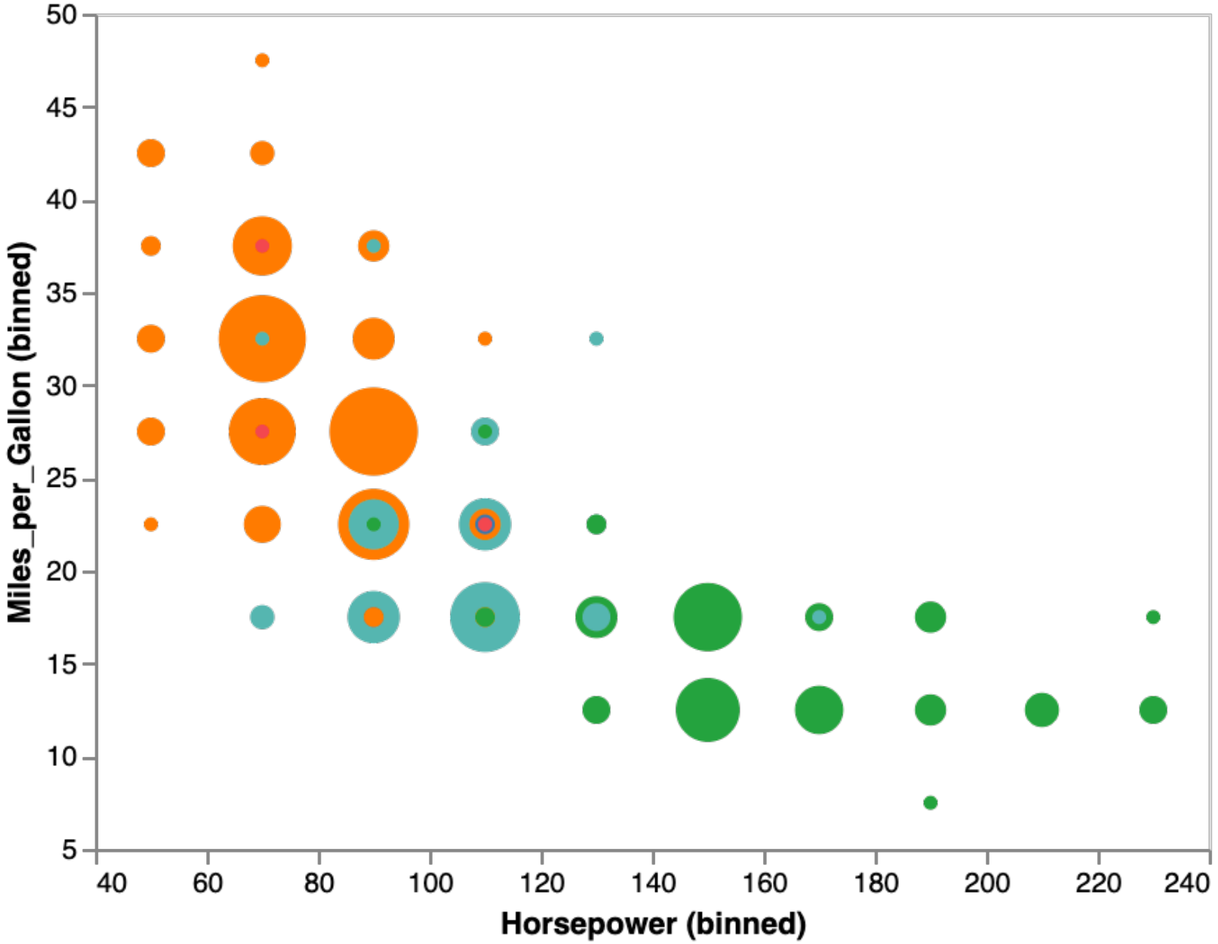

```
markCircle()
  .data('data/cars.json')
  .encode(
    x().fieldQ('Horsepower'),
    y().fieldQ('Miles_per_Gallon')
  )
```

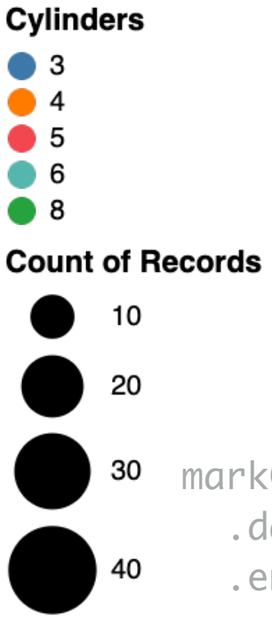
Vega-Lite: 2D Density




```
markCircle()
  .data('data/cars.json')
  .encode(
    x().fieldQ('Horsepower').bin(true),
    y().fieldQ('Miles_per_Gallon').bin(true),
    size().count()
  )
```

Vega-Lite: 2D Density (Colored)



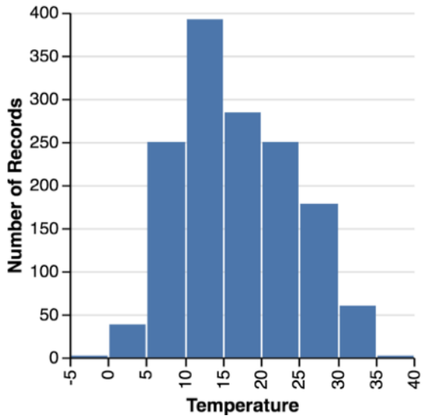



```
markCircle()
  .data('data/cars.json')
  .encode(
    x().fieldQ('Horsepower').bin(true),
    y().fieldQ('Miles_per_Gallon').bin(true),
    size().count(),
    color().fieldN('Cylinders')
  )
```

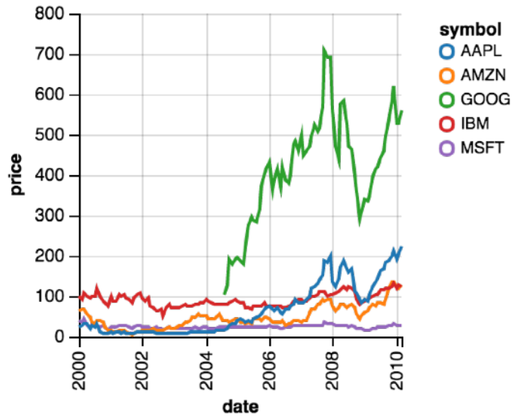
RESEARCH GOAL:

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

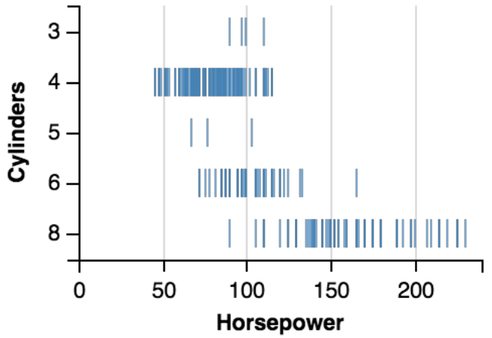
Histogram



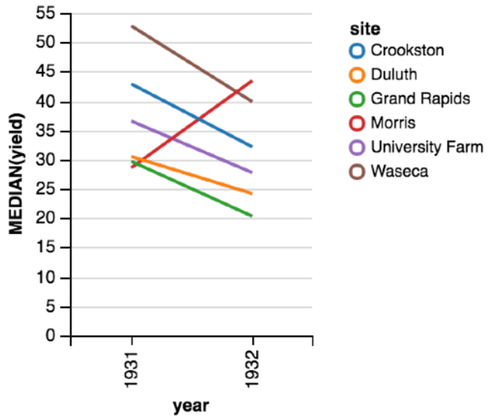
Line Chart



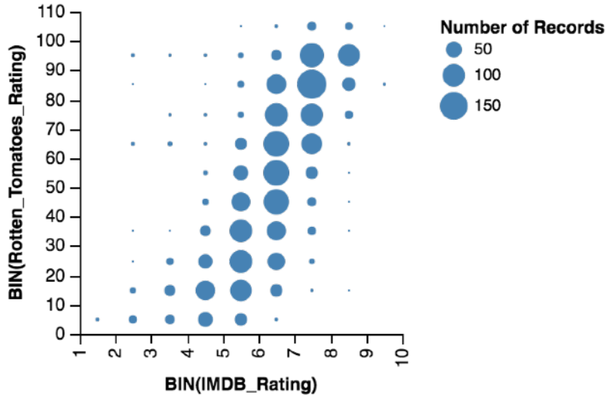
Strip Plot



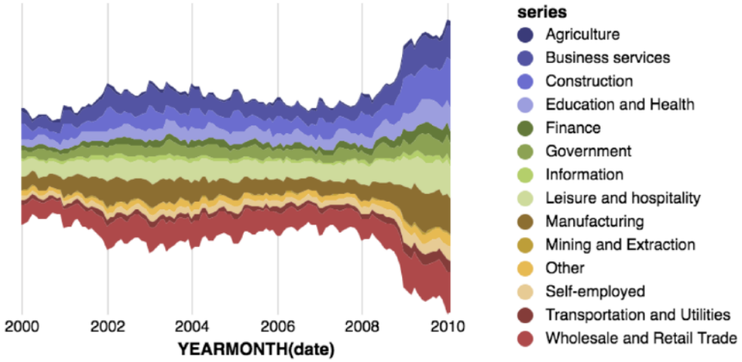
Slope Graph



Binned Scatter Plot

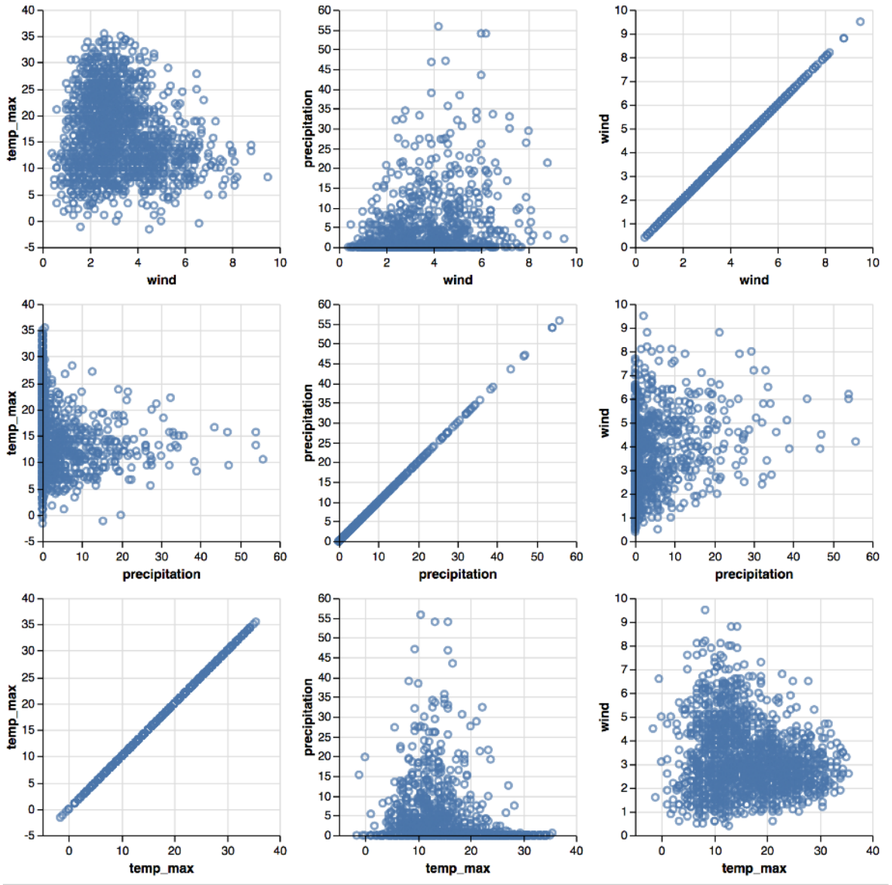


Area Chart

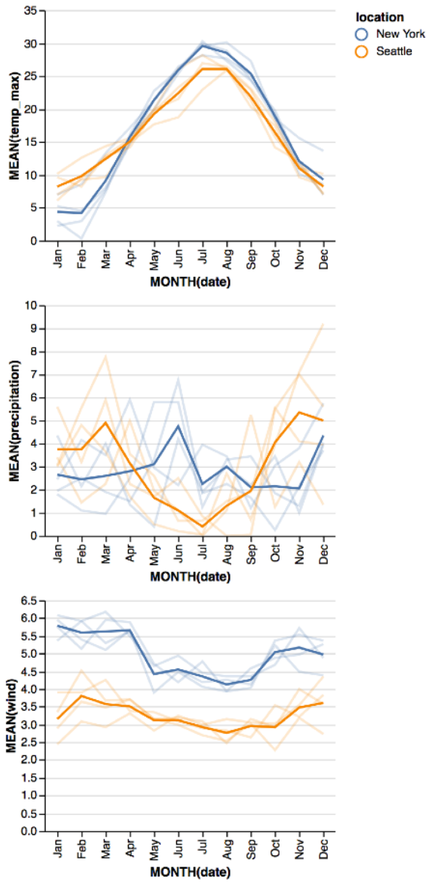


Vega-Lite: A Grammar of Graphics

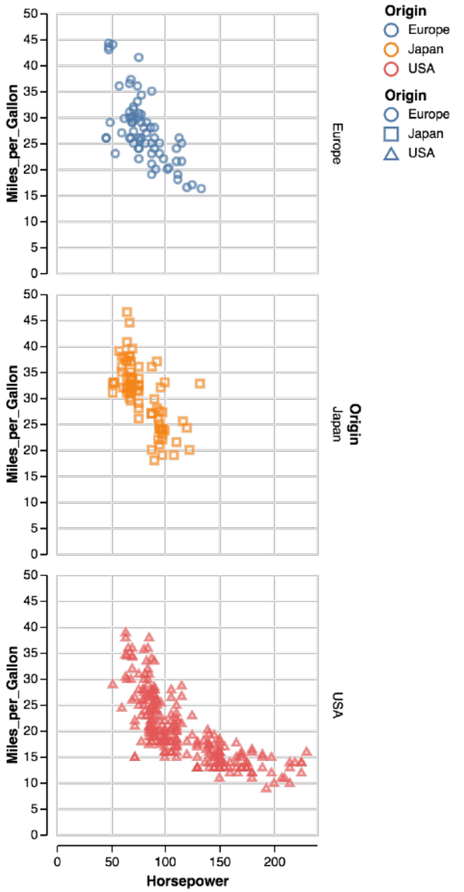
Scatter Plot Matrix



Concatenated & Layered View

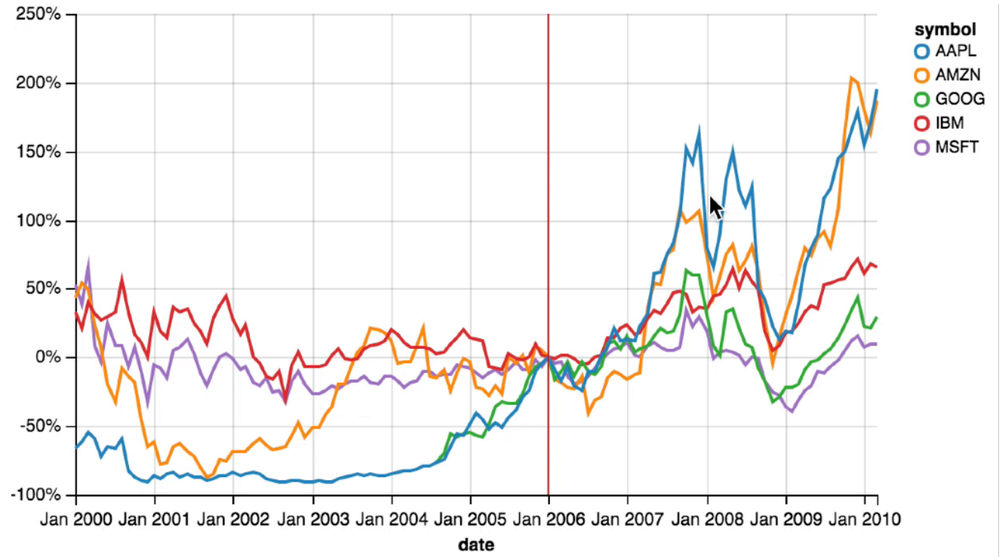


Faceted View

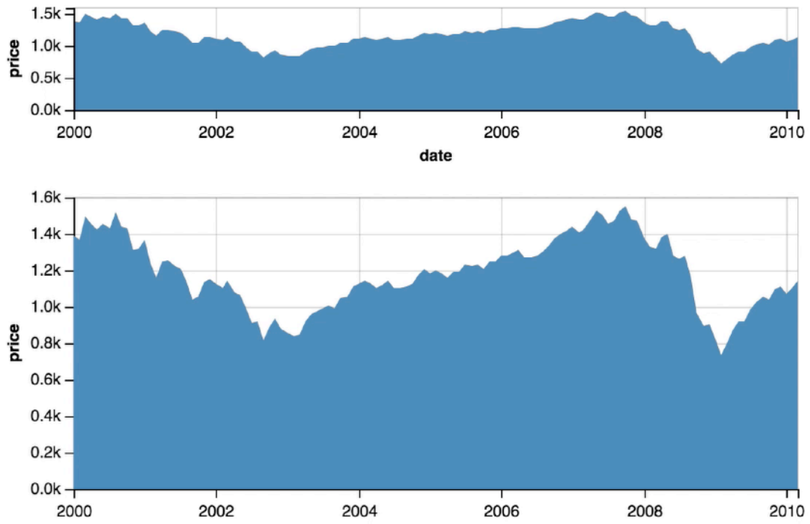


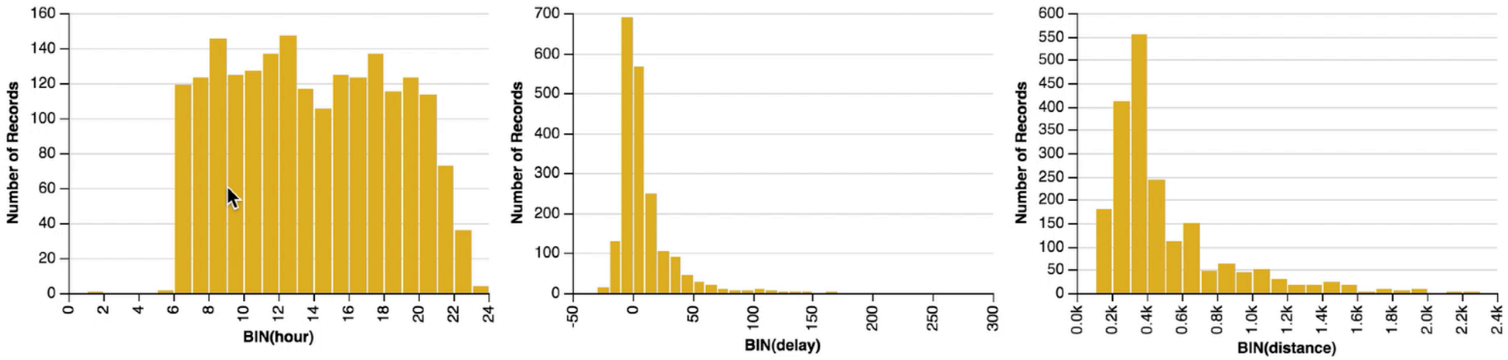
Vega-Lite: A Grammar of Multi-View Graphics

Indexed Chart



Focus + Context

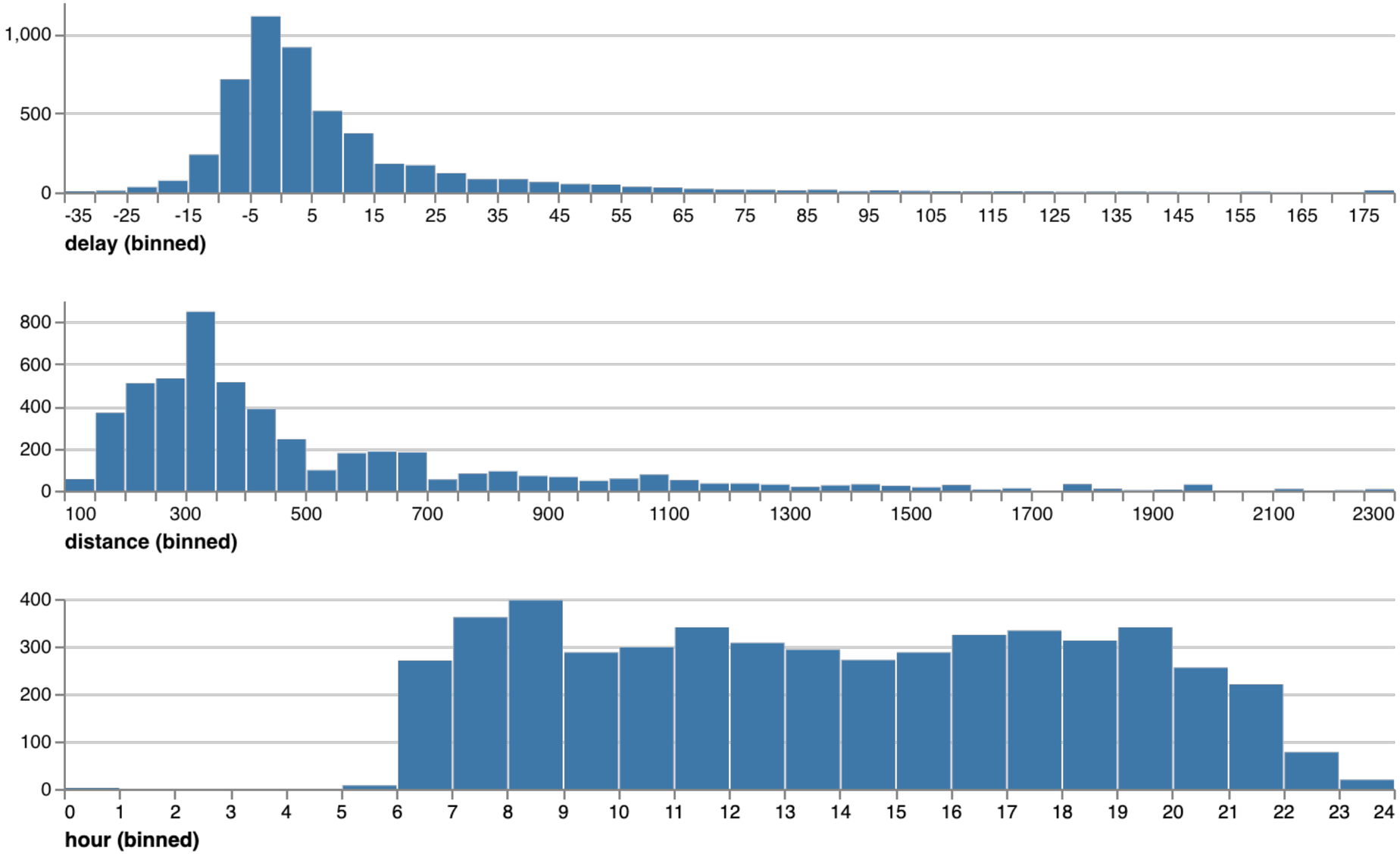




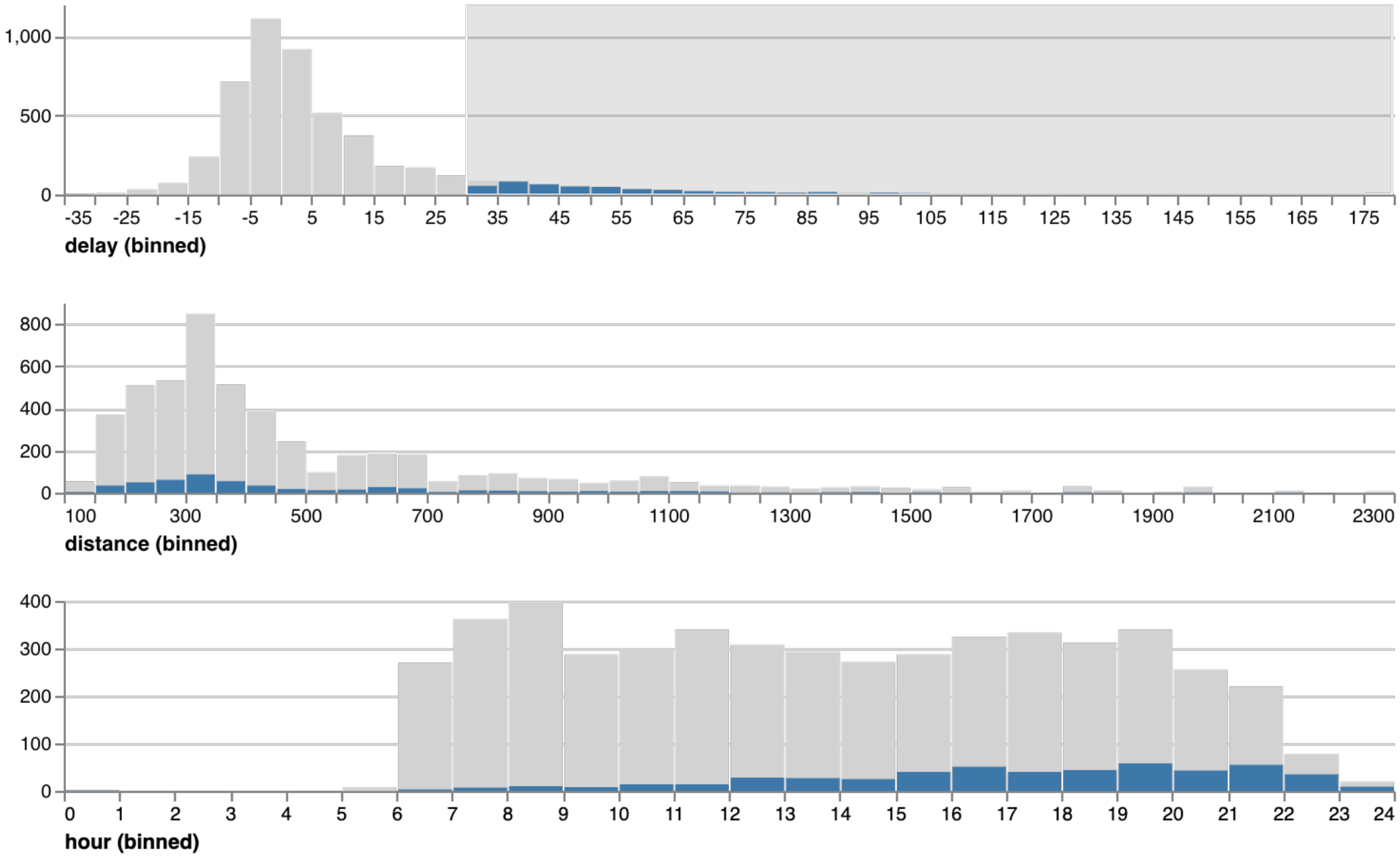
Cross-Filtering

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

Cross-Filtering in Vega-Lite

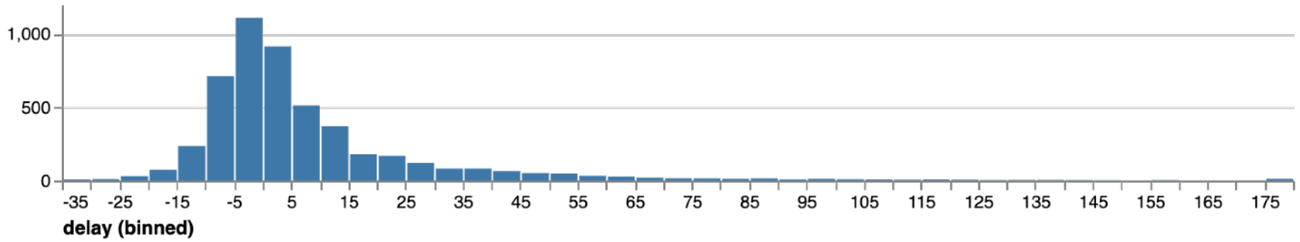


Cross-Filtering in Vega-Lite



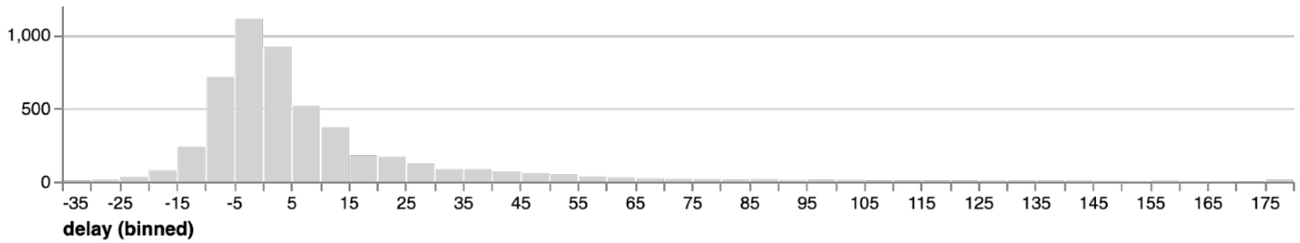
Cross-Filtering in Vega-Lite

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



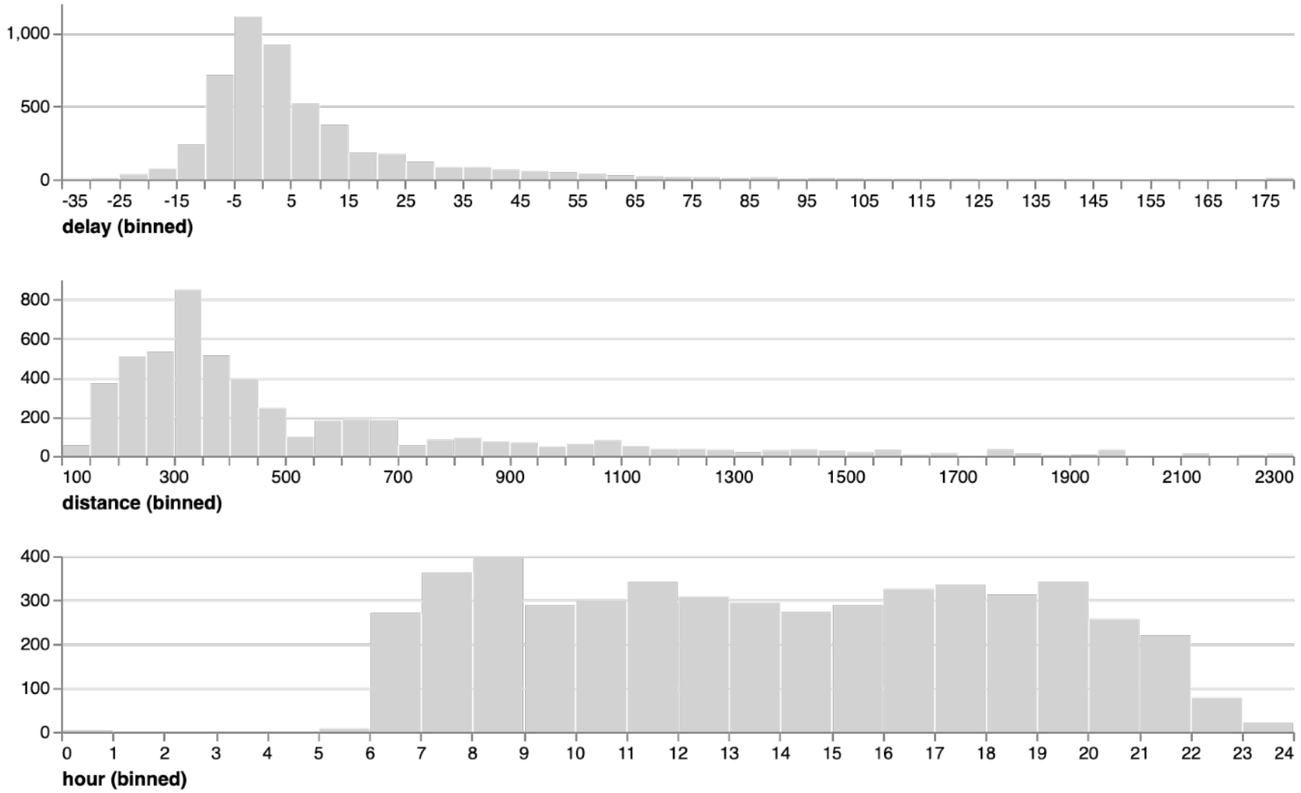
Cross-Filtering in Vega-Lite

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



Cross-Filtering in Vega-Lite

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



Cross-Filtering in Vega-Lite

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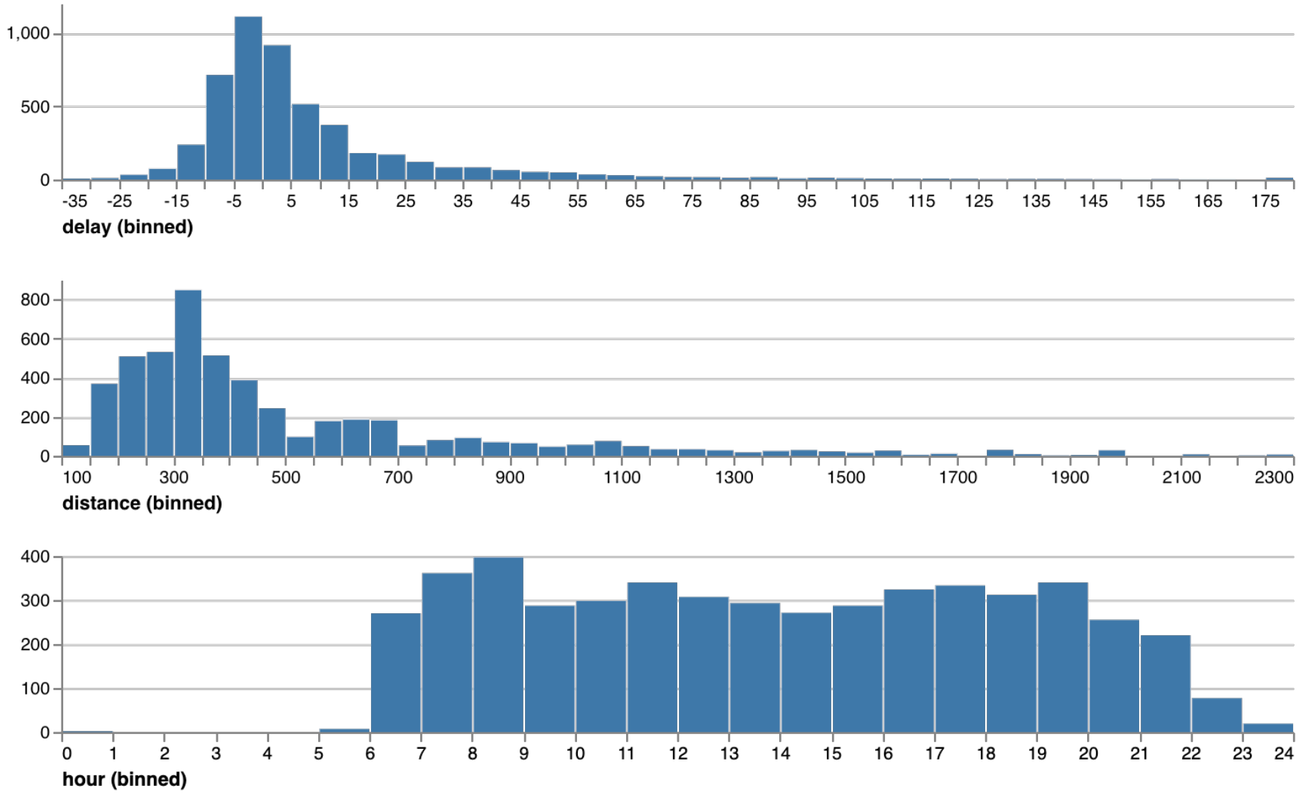
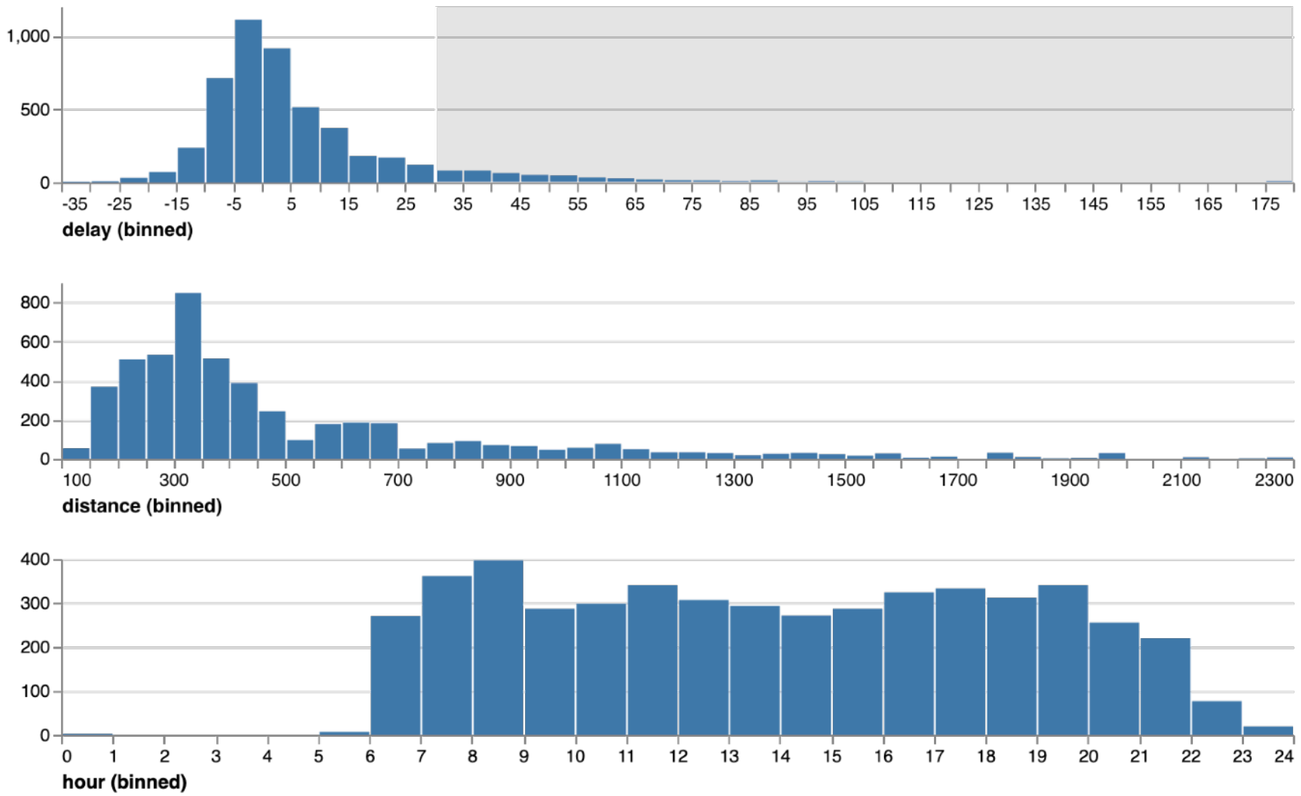
```



Cross-Filtering in Vega-Lite

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

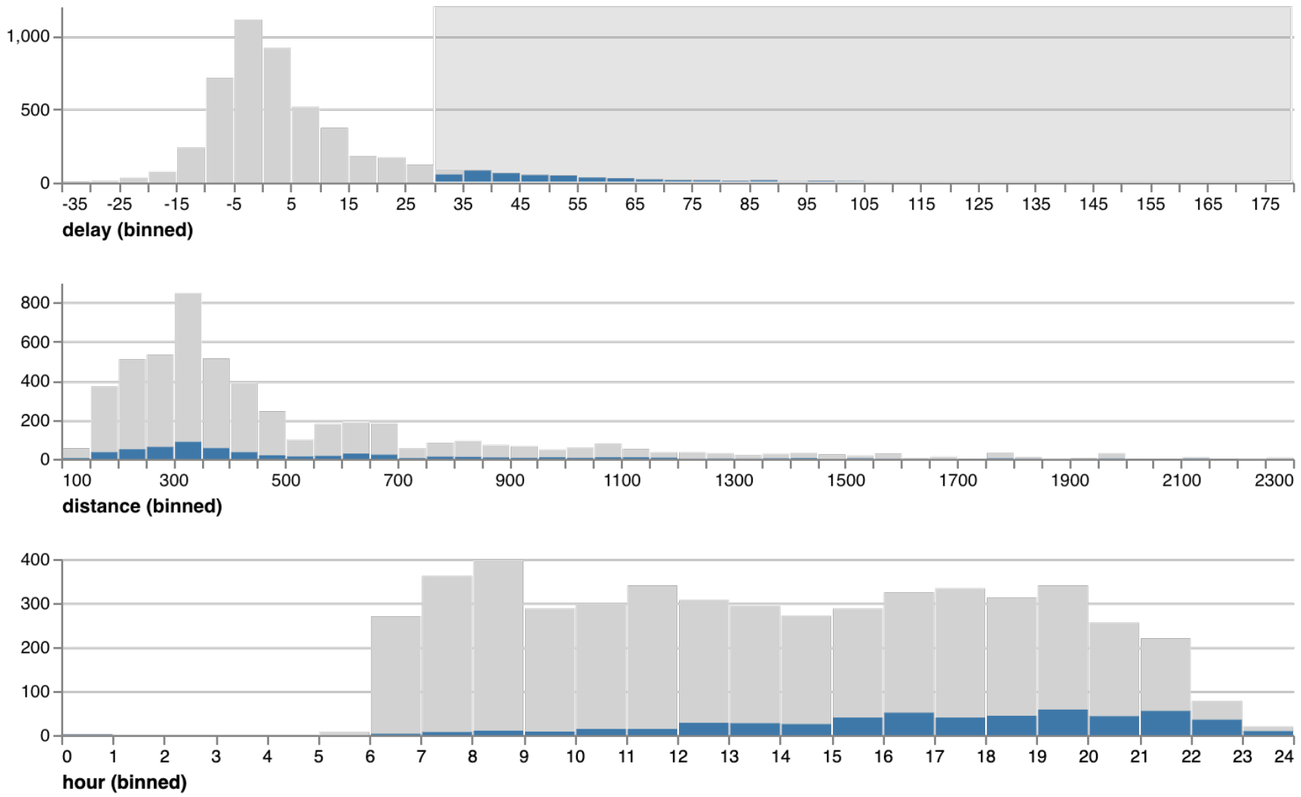
layer(
  markBar().encode(
    x().fieldQ(repeat('row')).bin(true),
    y().count(),
    color().value('lightgrey')
  ).select(brush),
  markBar().encode(
    x().fieldQ(repeat('row')).bin(true),
    y().count()
  )
)
.repeat({row: ['delay', 'distance', 'hour']})
.data('data/flights.json')
```



Cross-Filtering in Vega-Lite

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

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



Cross-Filtering in Vega-Lite

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brush = selectInterval.encodings('x')

layer(
  markBar().encode(
    x().fieldQ(repeat('row')).bin(true),
    y().count(),
    color().value('lightgrey')
  ).select(brush),
  markBar().encode(
    x().fieldQ(repeat('row')).bin(true),
    y().count()
  ).transform(filter(brush))
)
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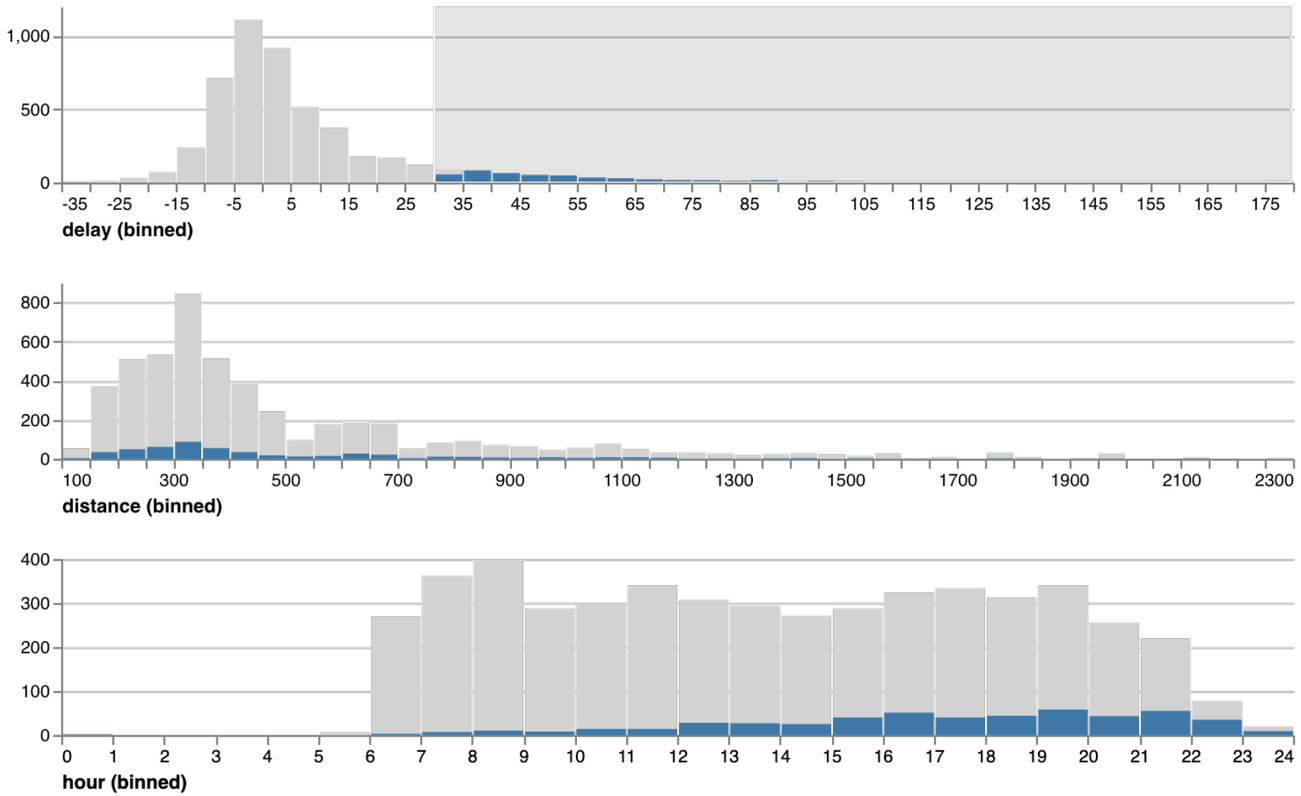
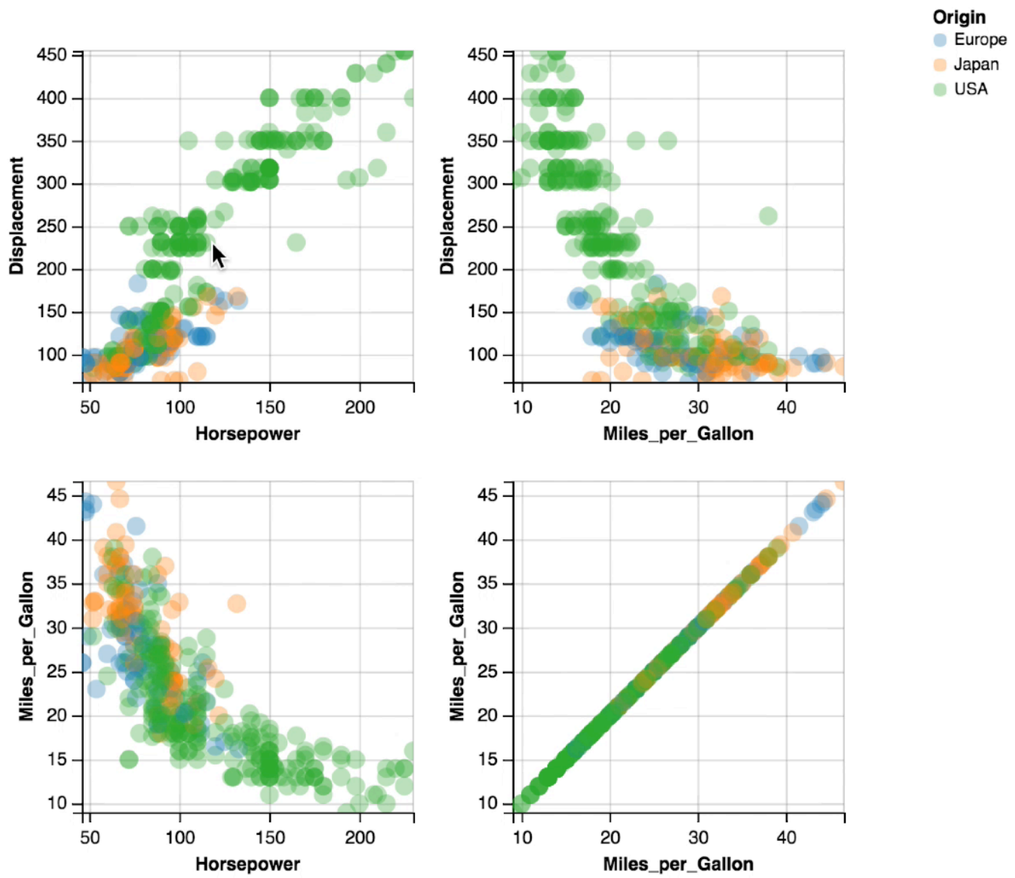
```



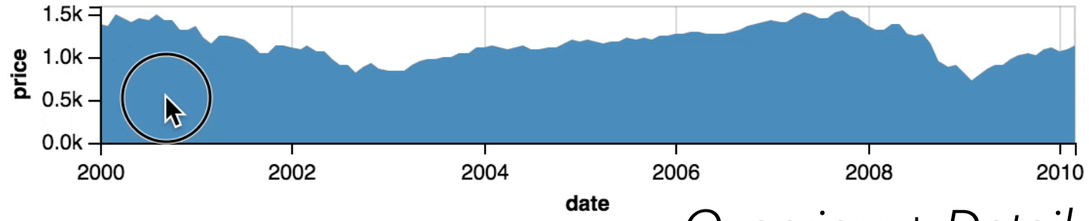
Multi-view interactive graphics in ~10 lines of code!

Interactive Selections

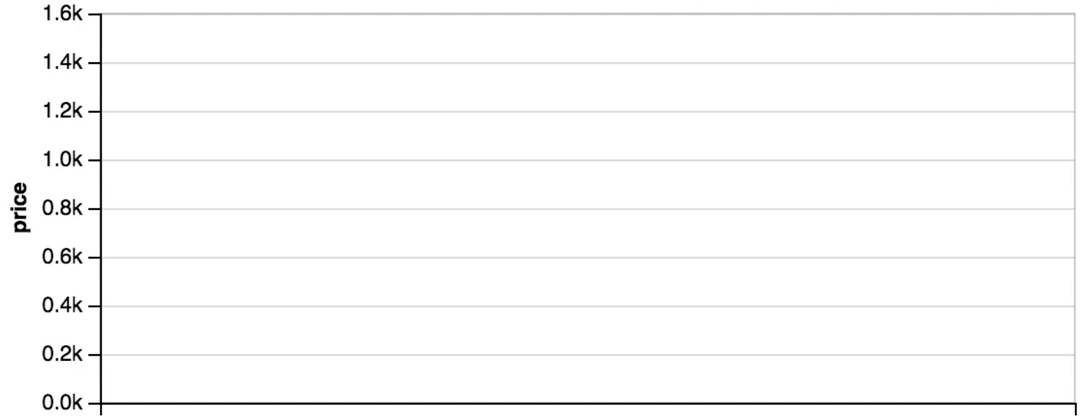
Selections *invert* scales and *parameterize* graphics

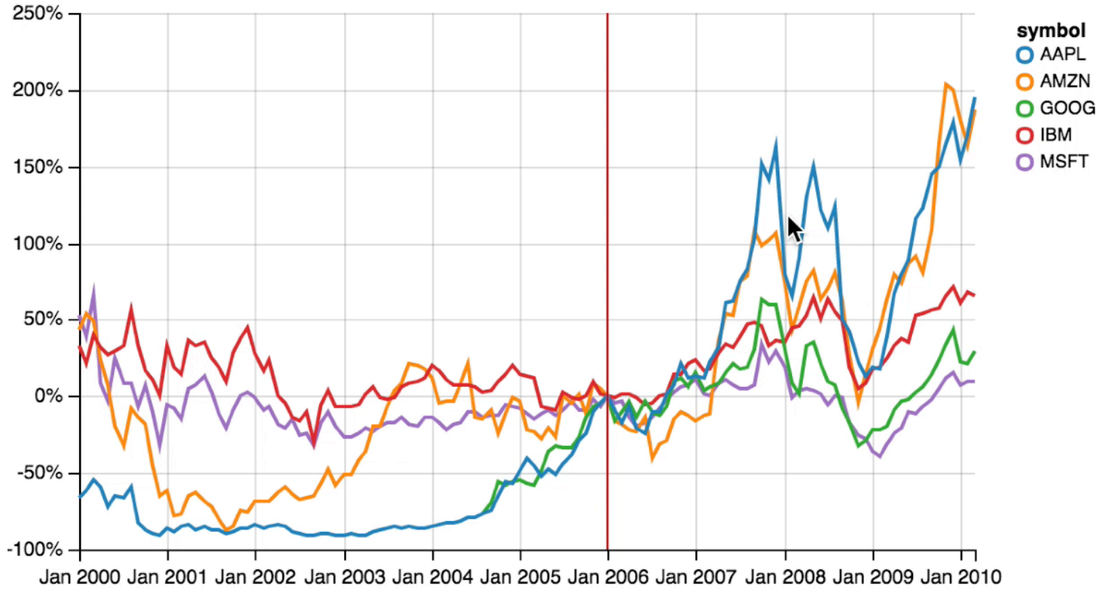


Bind selection to scale domains:
Synchronized Pan & Zoom!



Overview + Detail





Parameterized Transformations

Altair

3.0.0

Search docs

GETTING STARTED

Overview

Installation

Basic Statistical Visualization

GALLERY

Example Gallery

USER GUIDE

Docs » Altair: Declarative Visualization in Python

View page source

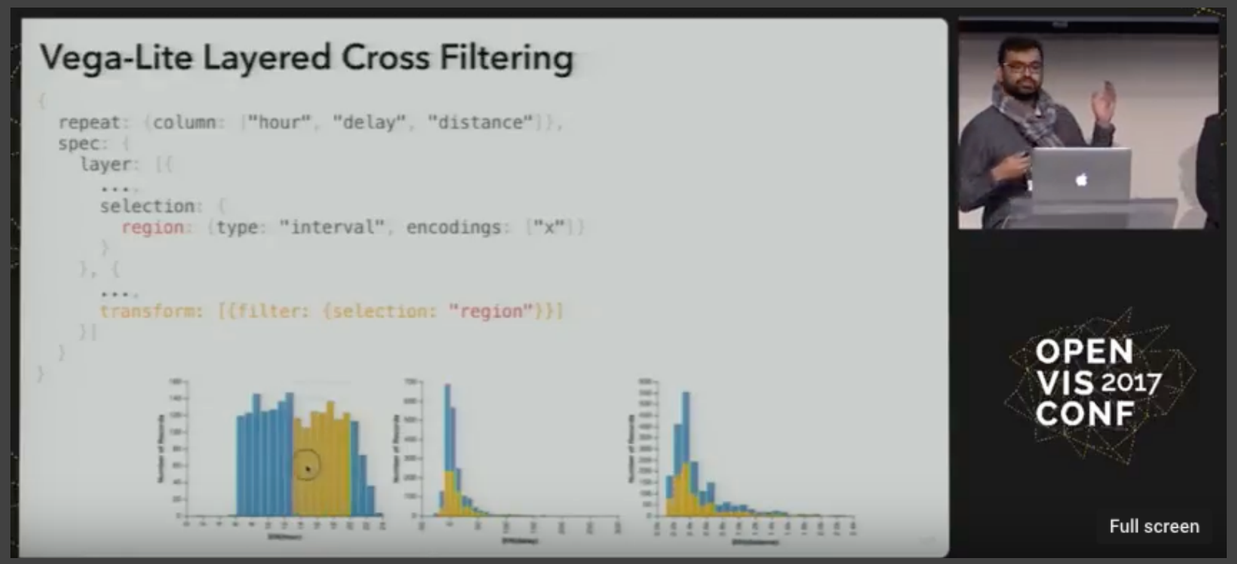
Altair: Declarative Visualization in Python

Altair is a declarative statistical visualization library for Python, based on Vega and Vega-Lite, and the source is available on GitHub.

Altair: Vega-Lite in Python

Led by Jake VanderPlas & Brian Granger

To Learn More…



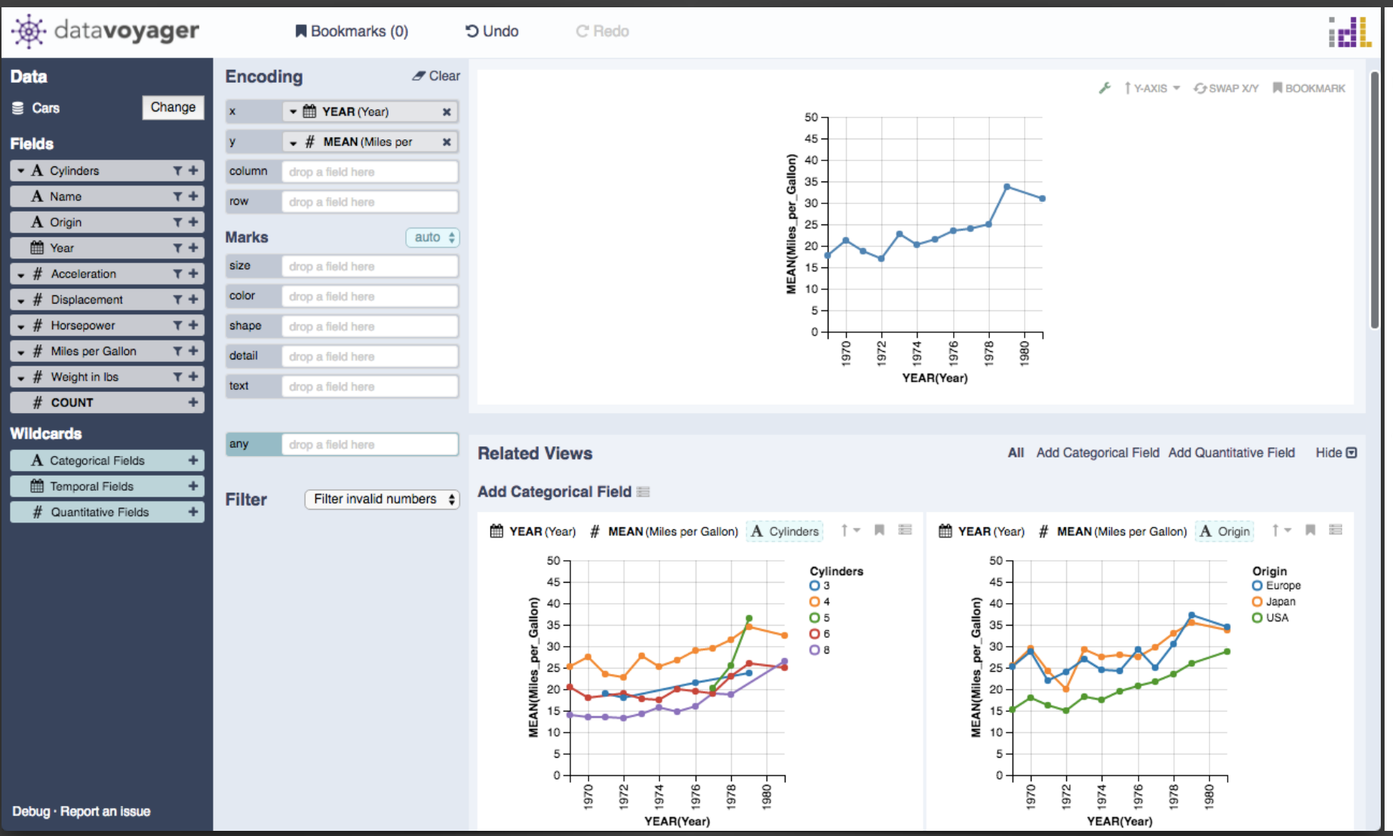
Vega-Lite: A Grammar of Interactive Graphics, *OpenVis Conf 2017*

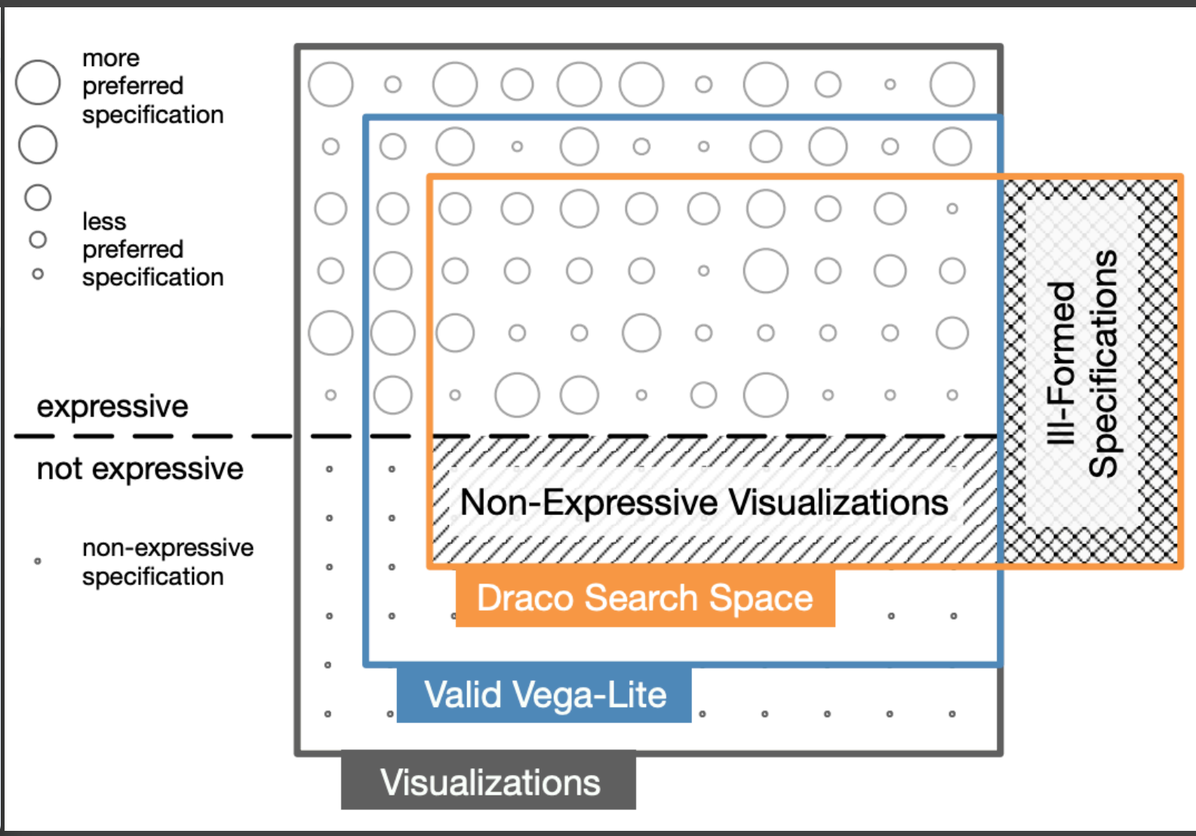
youtu.be/9uaHRWj04D4

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

youtu.be/aRxahWy-ul8

How might we support more **effective data exploration?**





Voyager, Wongsuphasawat et al.

Draco, Moritz et al.

Enabling Computational Search & Design

The Grammar of Graphics as a formal model for automated reasoning over the space of visualization designs.

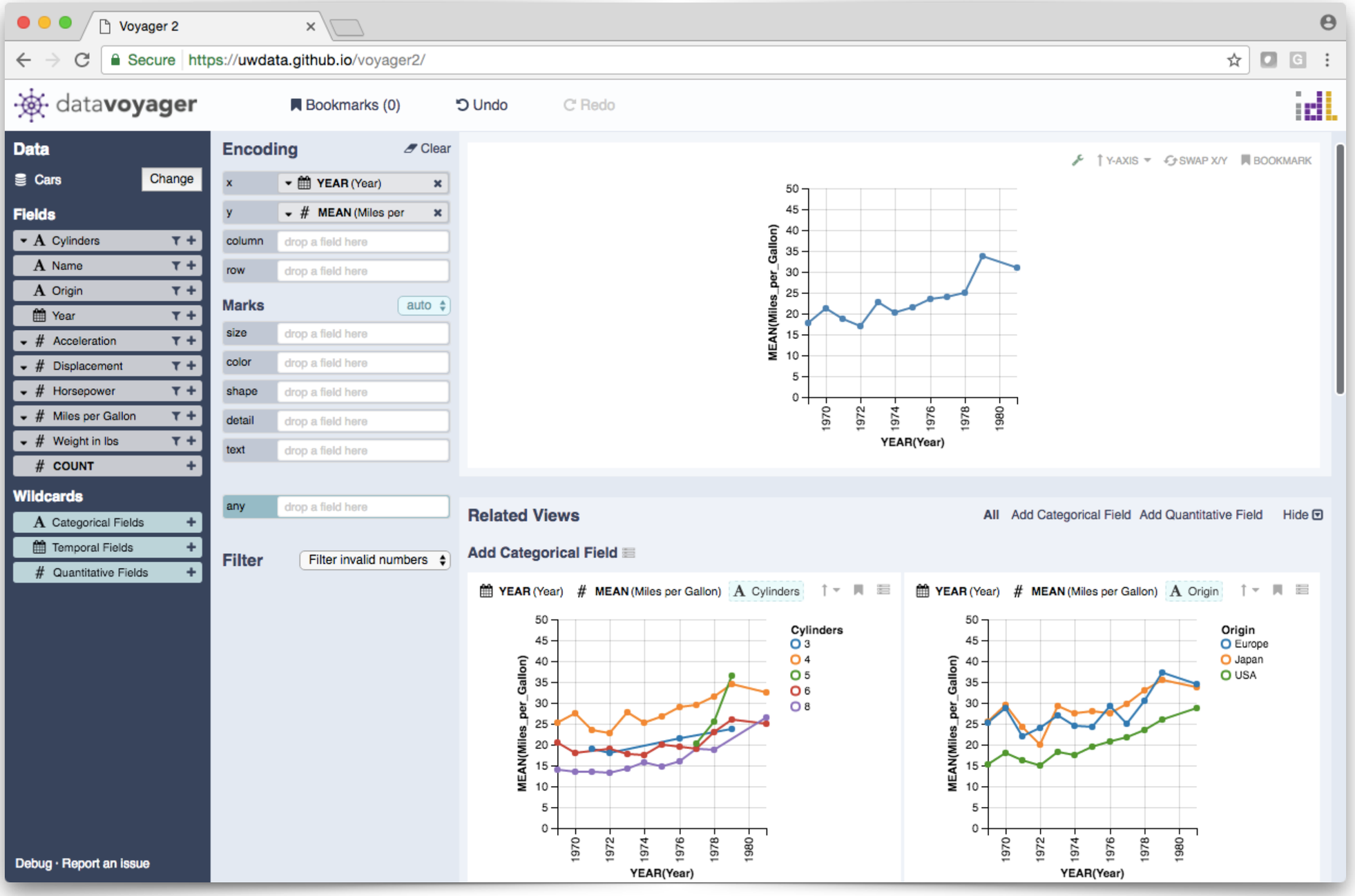
Common analysis pitfalls:

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*.

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.”