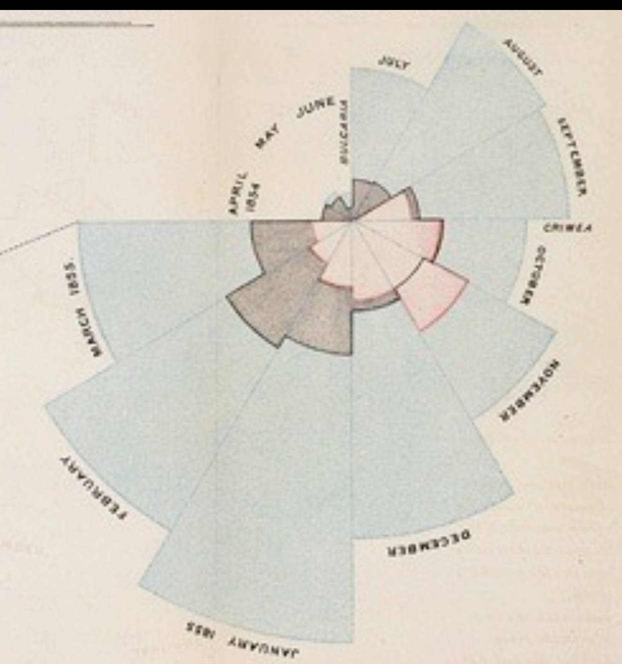
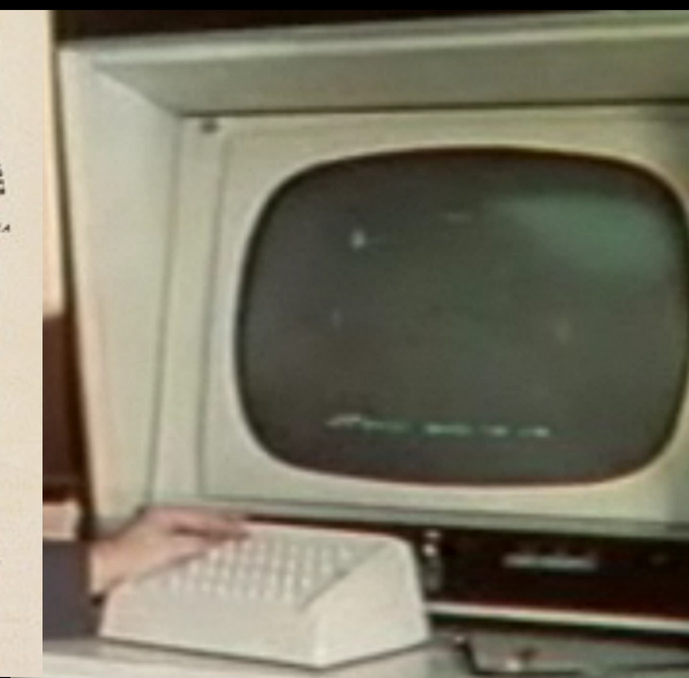
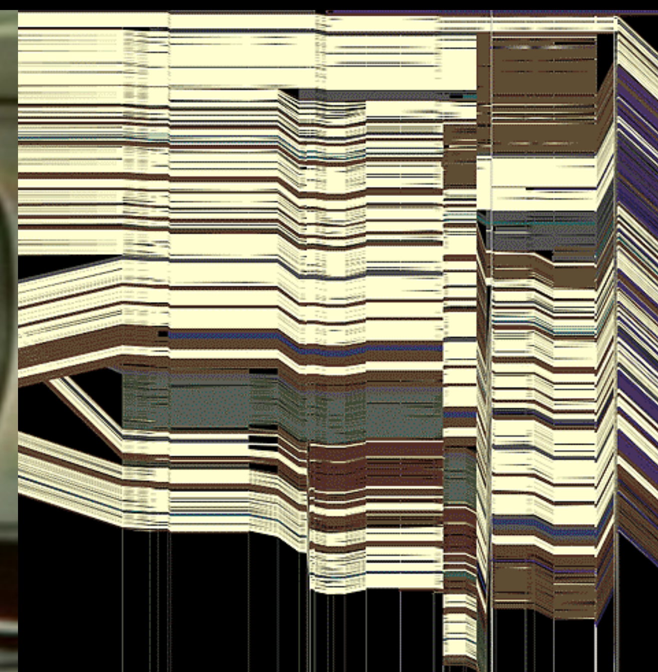
CSE 512 - Data Visualization

Visualization Tools







Jeffrey Heer University of Washington

How do people create visualizations?

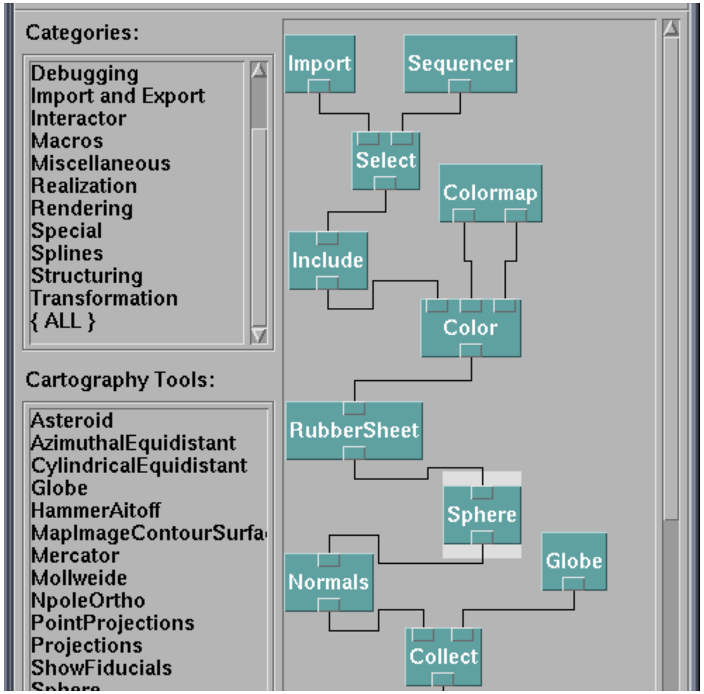


Chart Typology

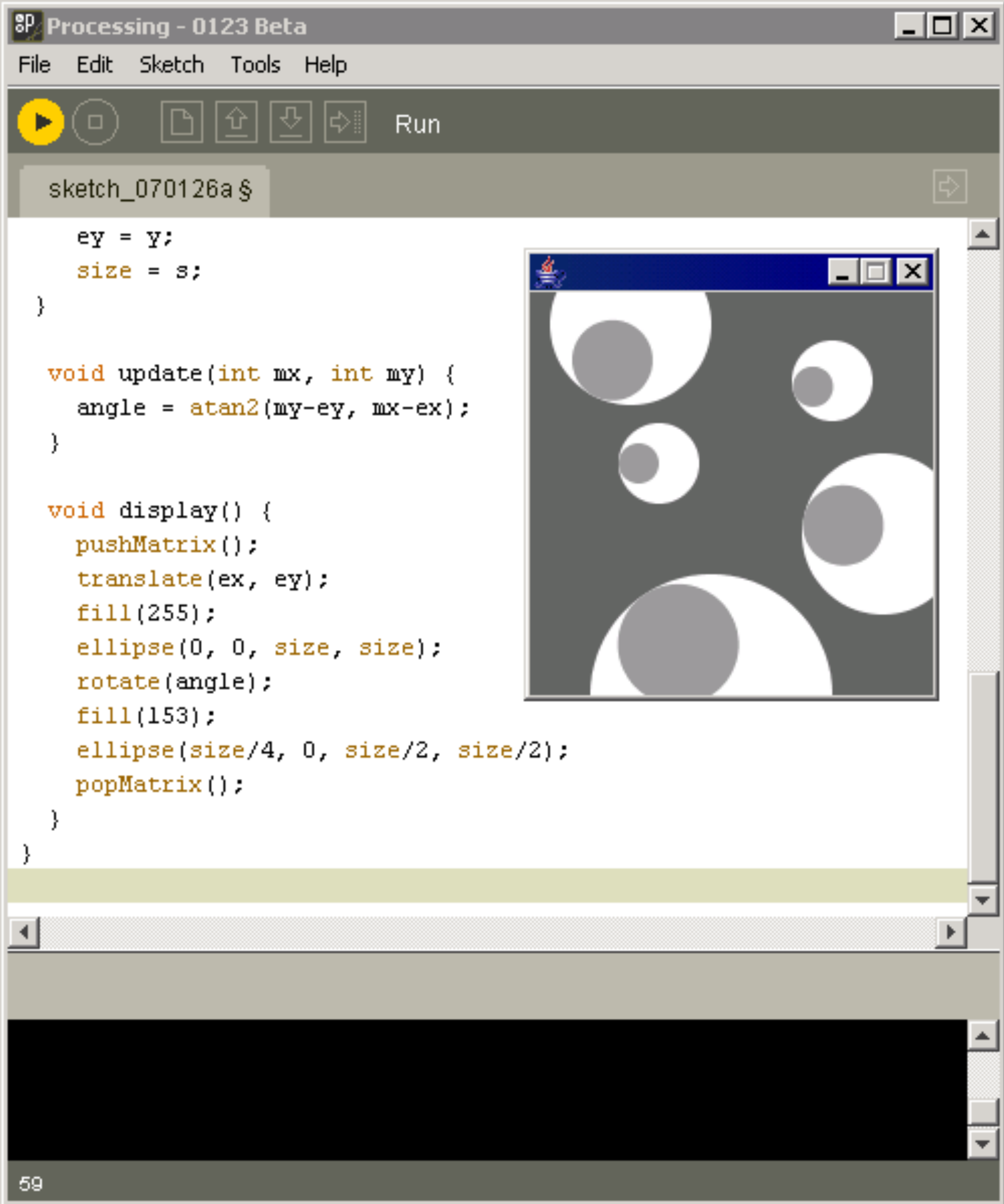
Pick from a stock of templates
Easy-to-use but limited expressiveness
Prohibits novel designs, new data types

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

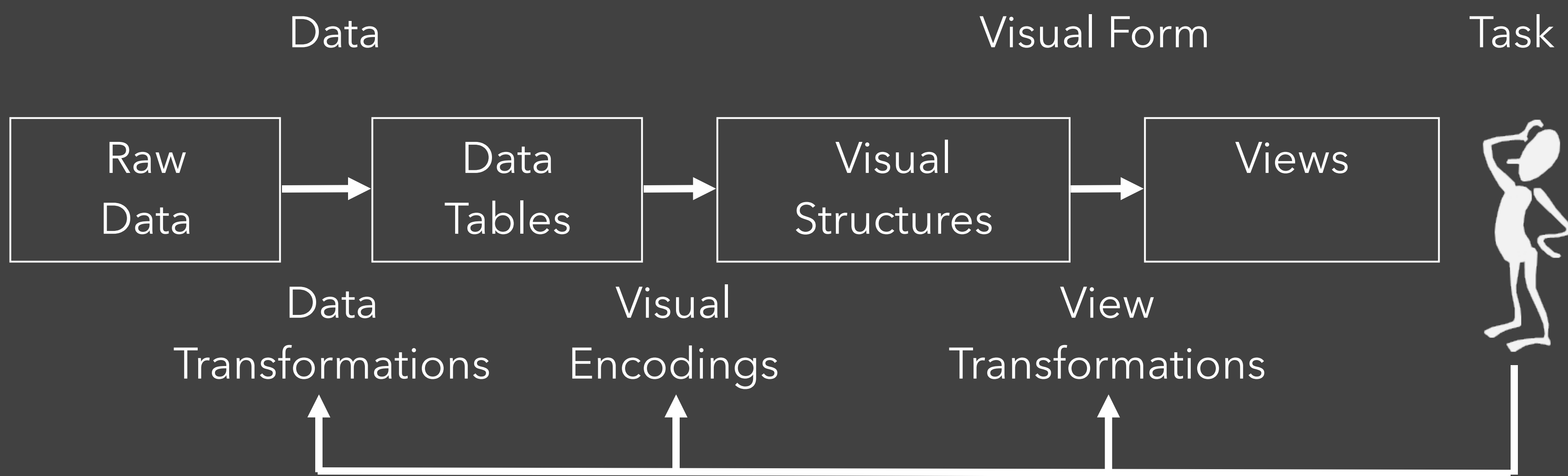
Processing, OpenGL, Java2D

Component Architectures

Prefuse, Flare, Improvise, VTK

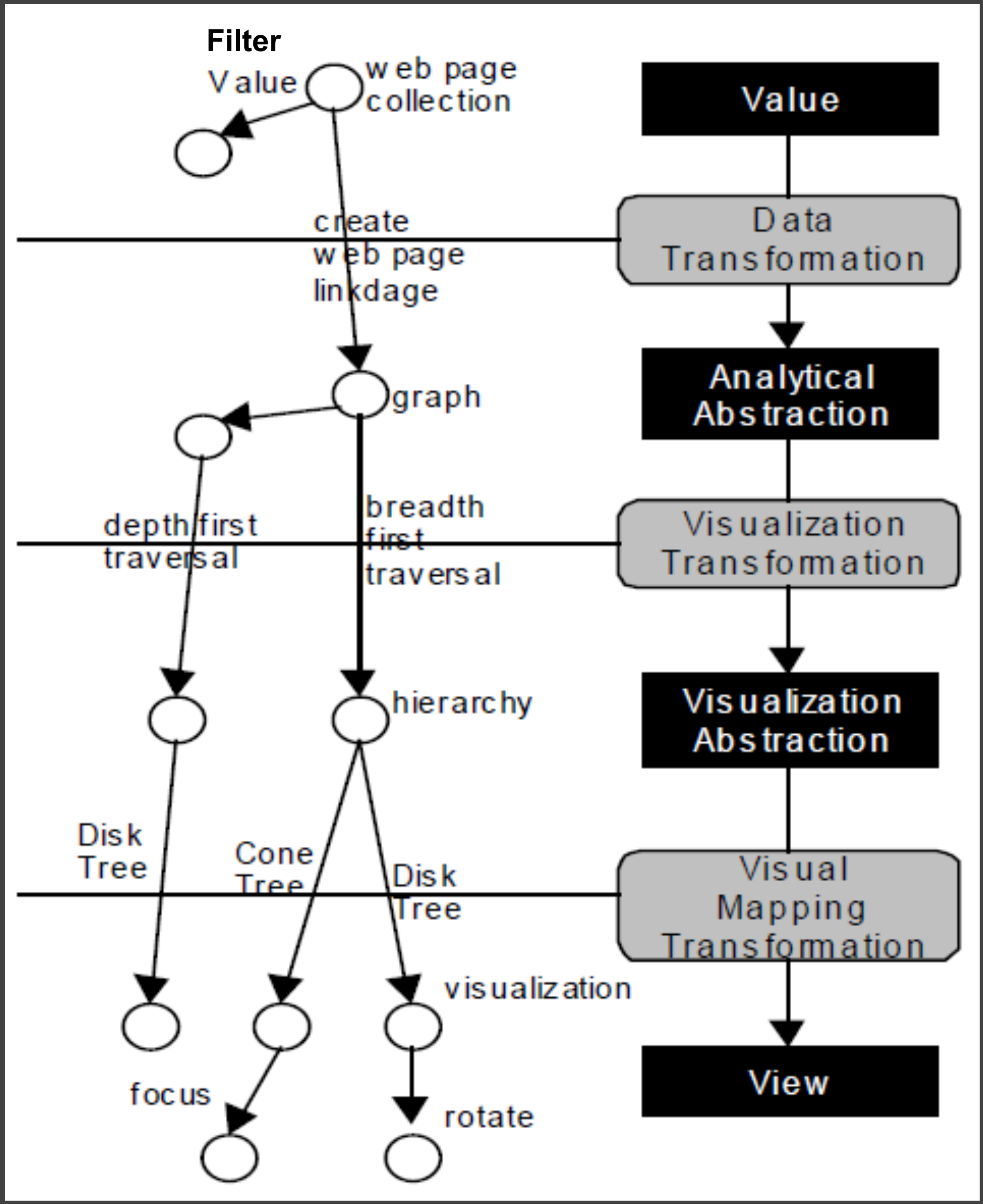
Graphics APIs

Processing, OpenGL, Java2D


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

Data State Model

[Chi 98]



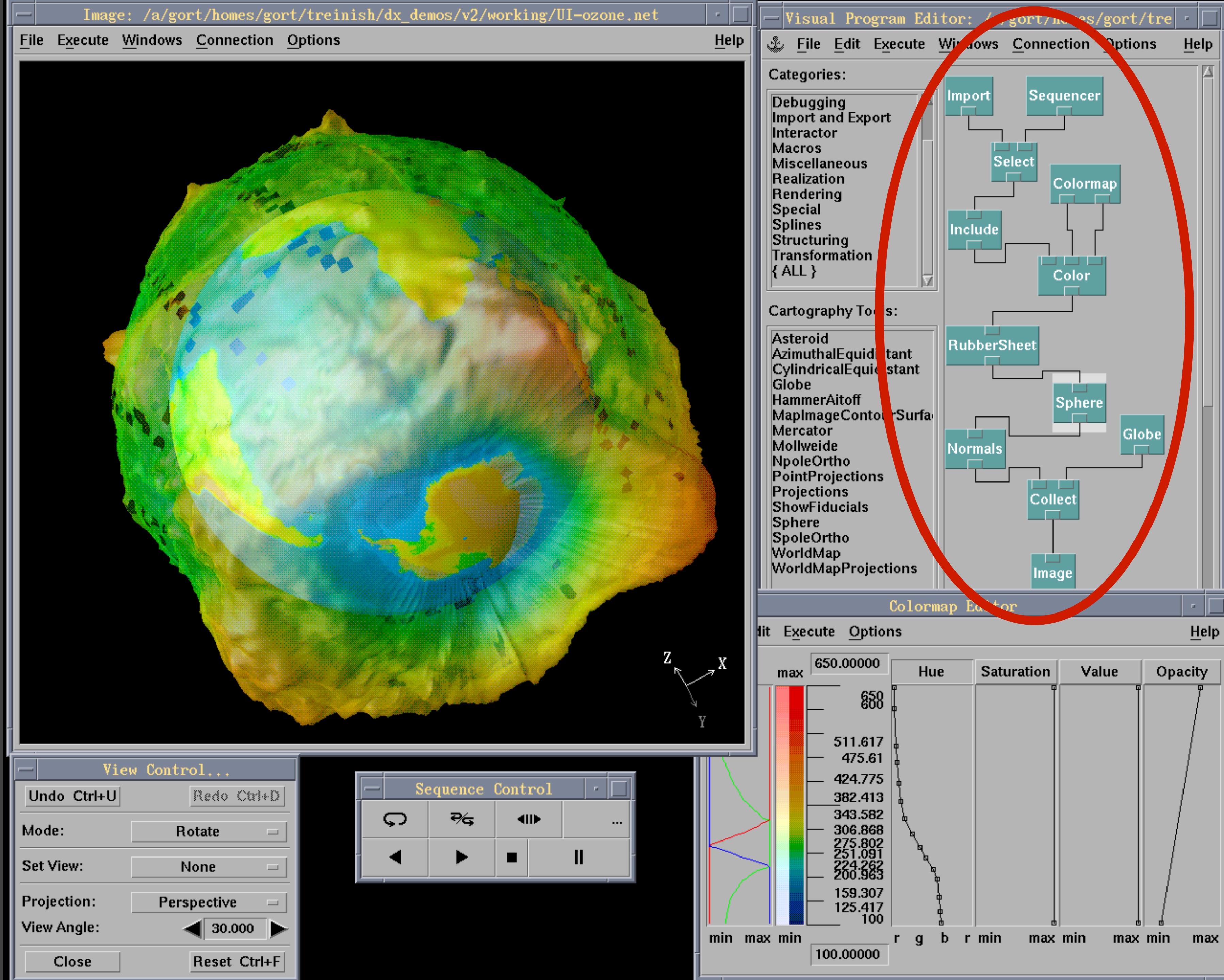


Image: /a/gort/homes/gort/treinish/dx_demos/v2/working/UI-ozone.net
File Execute Windows Connection Options Help
Visual Program Editor:
File Edit Execute Windows Connection Options Help
Categories:
Debugging
Import and Export
Interactor
Macros
Miscellaneous
Realization
Rendering
Special
Splines
Structuring
Transformation
{ ALL }
Cartography Tools:
Asteroid
CylindricalEquidistant
Globe
HammerAitoff
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
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275.802
251.091
224.262
200.963
159.307
125.417
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min max min r g b r min max min max min max
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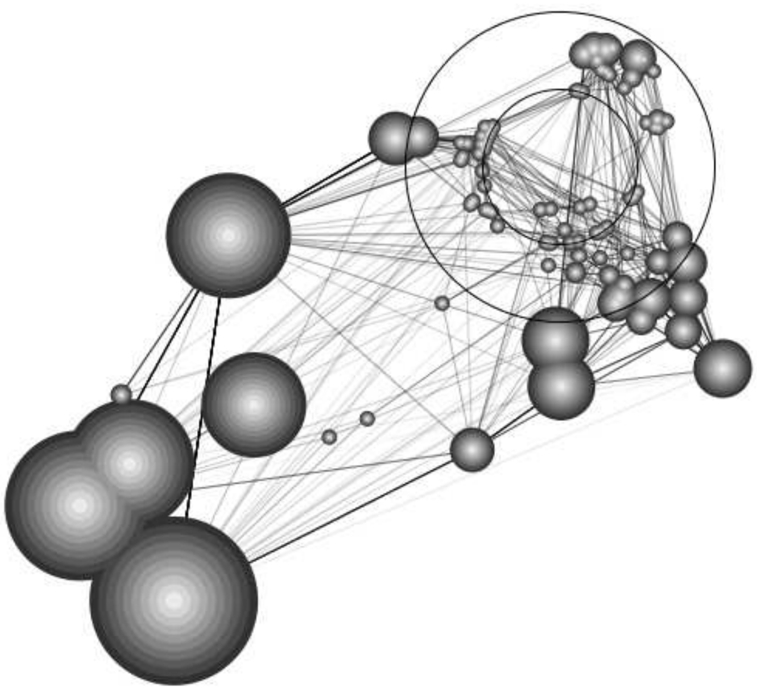
View Control...
Undo Ctrl+U
Redo Ctrl+D
Mode: Rotate
Set View: None
Projection: Perspective
View Angle: 30.000
Close
Reset Ctrl+F
Sequence Control
Z
X
Y

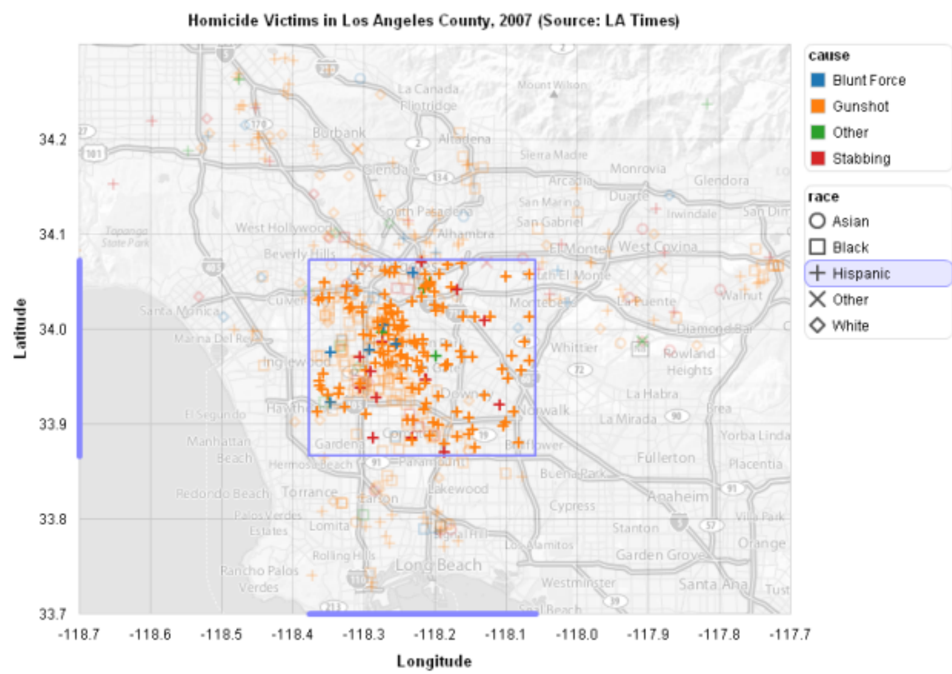
Prefuse & Flare

Operator-based toolkits for visualization design

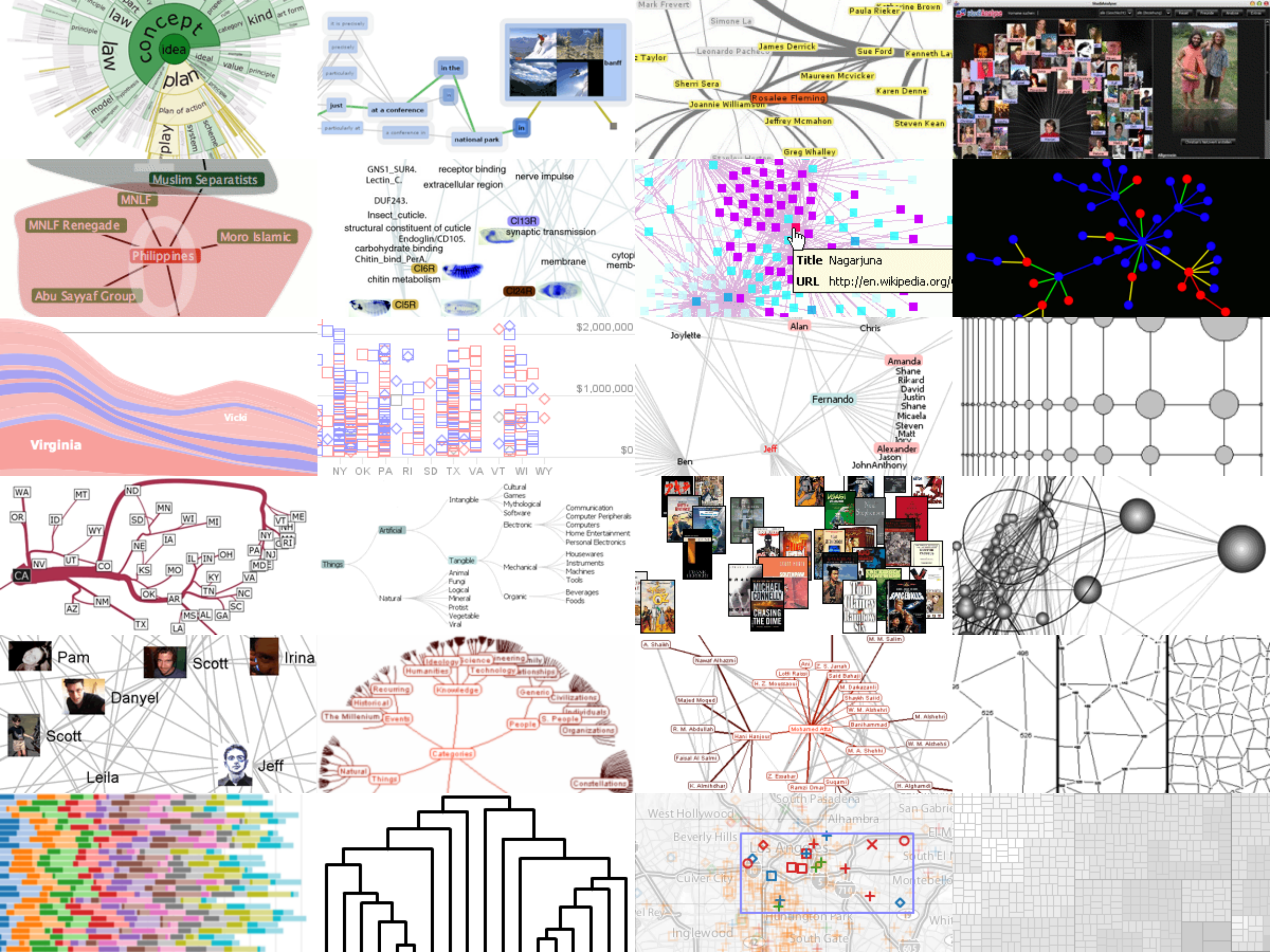
Vis = (Input Data -> Visual Objects) + Operators



Prefuse (http://prefuse.org)



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



concept
idea
law
plan
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value
principle
plan of action
play
system
scheme
model
in the
at a conference
national park
just
in
banff
Mark Frevert
Simone La
Paula Rieker
Katherine Brown
James Derrick
Leonardo Pacheco
Sue Ford
Kenneth Lay
Taylor
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.
Lectin_C.
receptor binding
extracellular region
nerve impulse
DUF243.
Insect_cuticle.
structural constituent of cuticle
Endoglin/CD105.
carbohydrate binding
Chitin_bind_PerA.
chitin metabolism
CI13R
synaptic transmission
CI6R
membrane
CI2AR
CI5R
Title Nagarjuna
URL http://en.wikipedia.org/
Virginia
Vicki
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$1,000,000
$0
NY OK PA RI SD TX VA VT WI WY
Joylette
Alan
Chris
Amanda
Shane
Rikard
David
Justin
Shane
Micaela
Steven
Matt
Fernando
Jeff
Ben
Alexander
Jason
JohnAnthony
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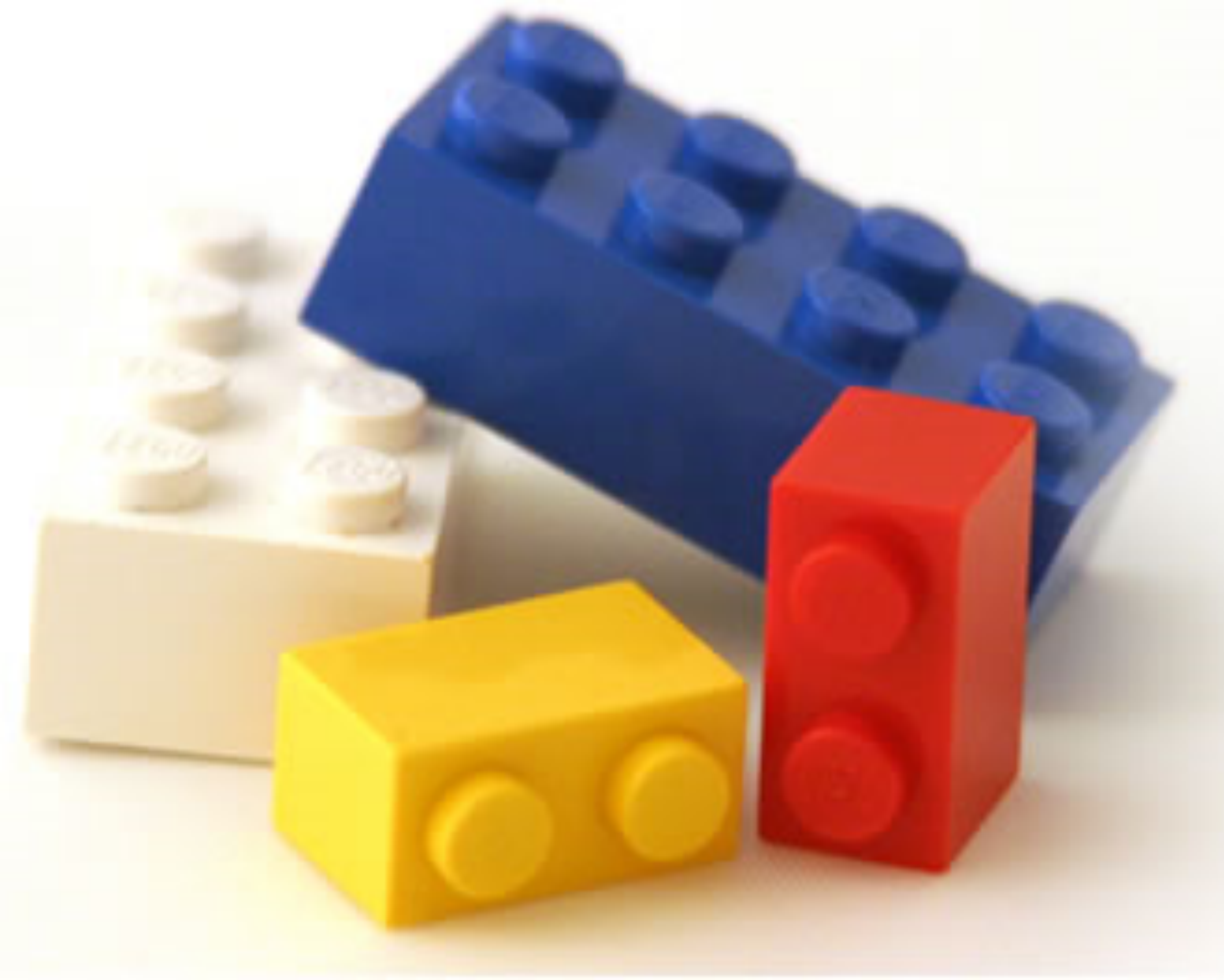
RI
Things
Artificial
Intangible
Cultural
Games
Mythological
Software
Electronic
Communication
Computer Peripherals
Computers
Home Entertainment
Personal Electronics
Tangible
Mechanical
Housewares
Instruments
Machines
Tools
Natural
Animal
Fungi
Logical
Mineral
Protist
Vegetable
Viral
Organic
Beverages
Foods
Pam
Scott
Irina
Danyel
Scott
Jeff
Leila
Humanities
Technology
Knowledge
Historical
Generic
Civilizations
The Millenium
Events
People
S. People
Organizations
Categories
Natural
Things
Constellations
A. Shaikh
M. M. Salim
Nawaf Alhazmi
Mohamed Atta
Hani Hanjour
Majed Moqed
R. M. Abdullah
Faisal Al Salmi
K. Almihdhar
Z. Essabar
Ramzi Omar
H. Alghamdi
M. Alshehri
W. M. Alshehri
M. A. Shehhi
Banihammad
West Hollywood
South Pasadena
San Gabriel
Alhambra
Beverly Hills
Los Angeles
Culver City
Montebello
Inglewood
Huntington Park
South Gate



Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

Chart Typologies

Excel, Many Eyes, Google Charts

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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.

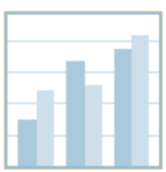
Learn more

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

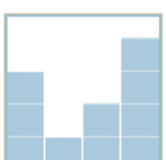
Compare a set of values



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.

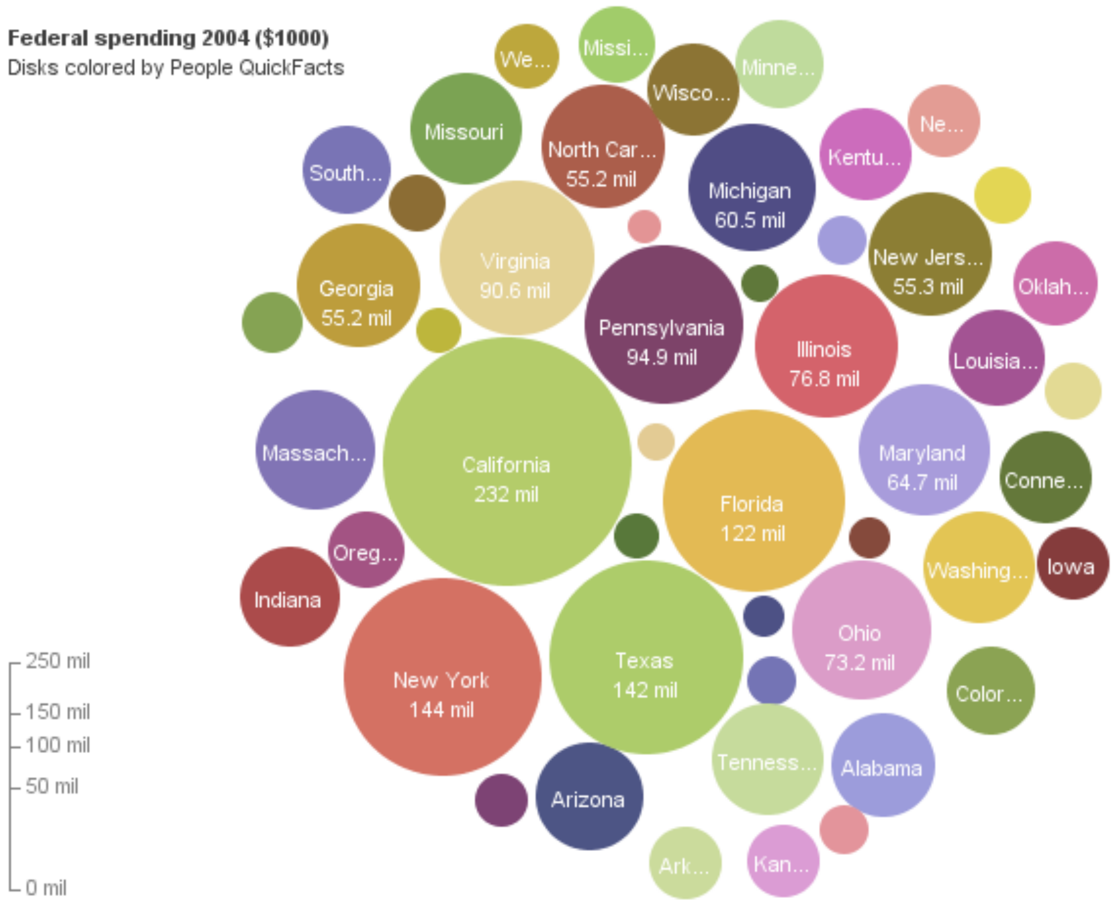
Learn more

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>>

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 fil... 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 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

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Prefuse, Flare, Improvise, VTK

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VizQL, ggplot2

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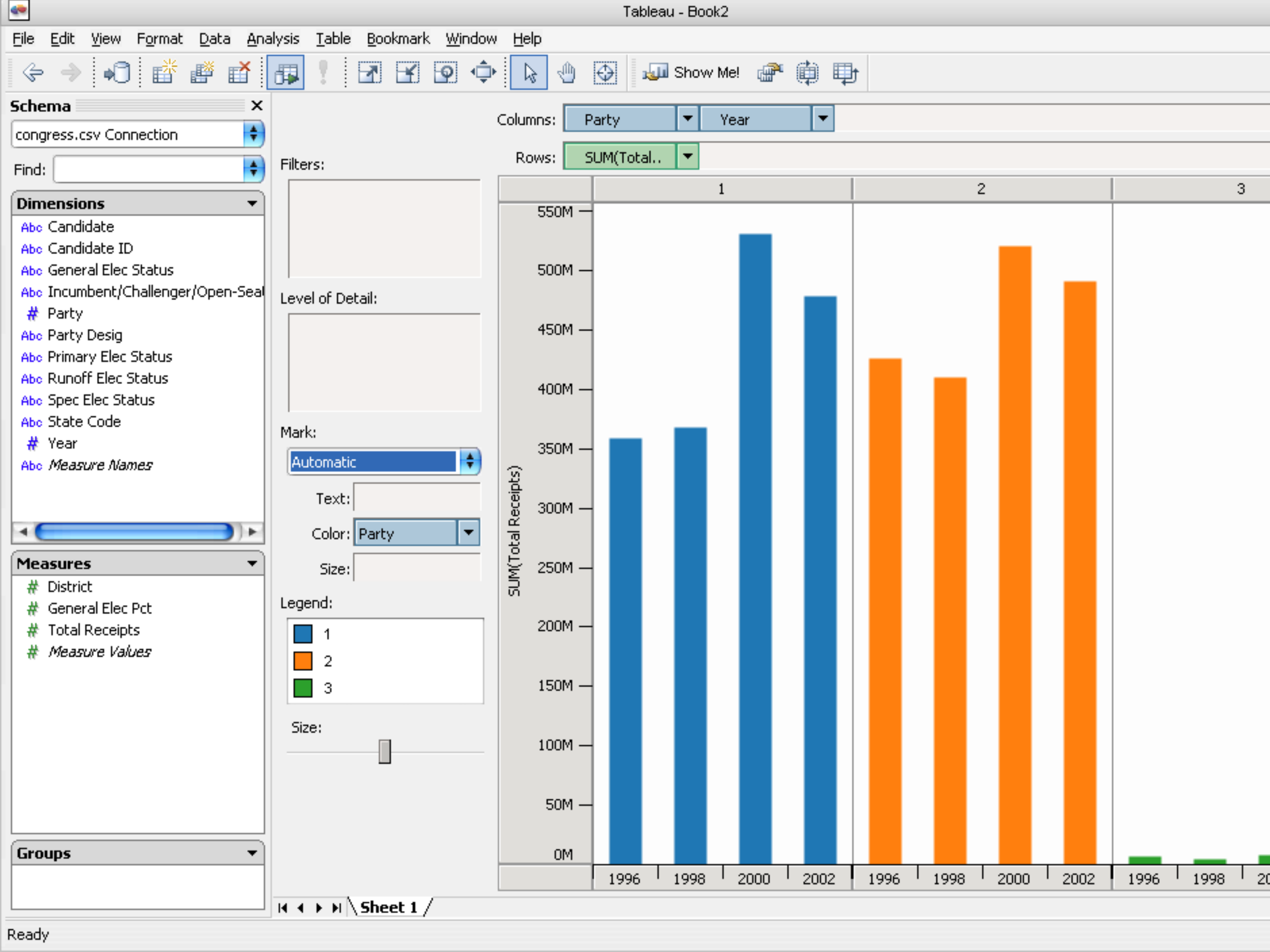


Tableau - Book2
File Edit View Format Data Analysis Table Bookmark Window Help
Show Me!
Schema
congress.csv Connection
Find:
Dimensions
Candidate
Candidate ID
General Elec Status
Incumbent/Challenger/Open-Seat
Party
Party Desig
Primary Elec Status
Runoff Elec Status
Spec Elec Status
State Code
Year
Measure 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
SUM(Total Receipts)
550M
500M
450M
400M
350M
300M
250M
200M
150M
100M
50M
0M
1996 1998 2000 2002 1996 1998 2000 2002 1996 1998
Sheet 1
Ready

Statistics and Computing

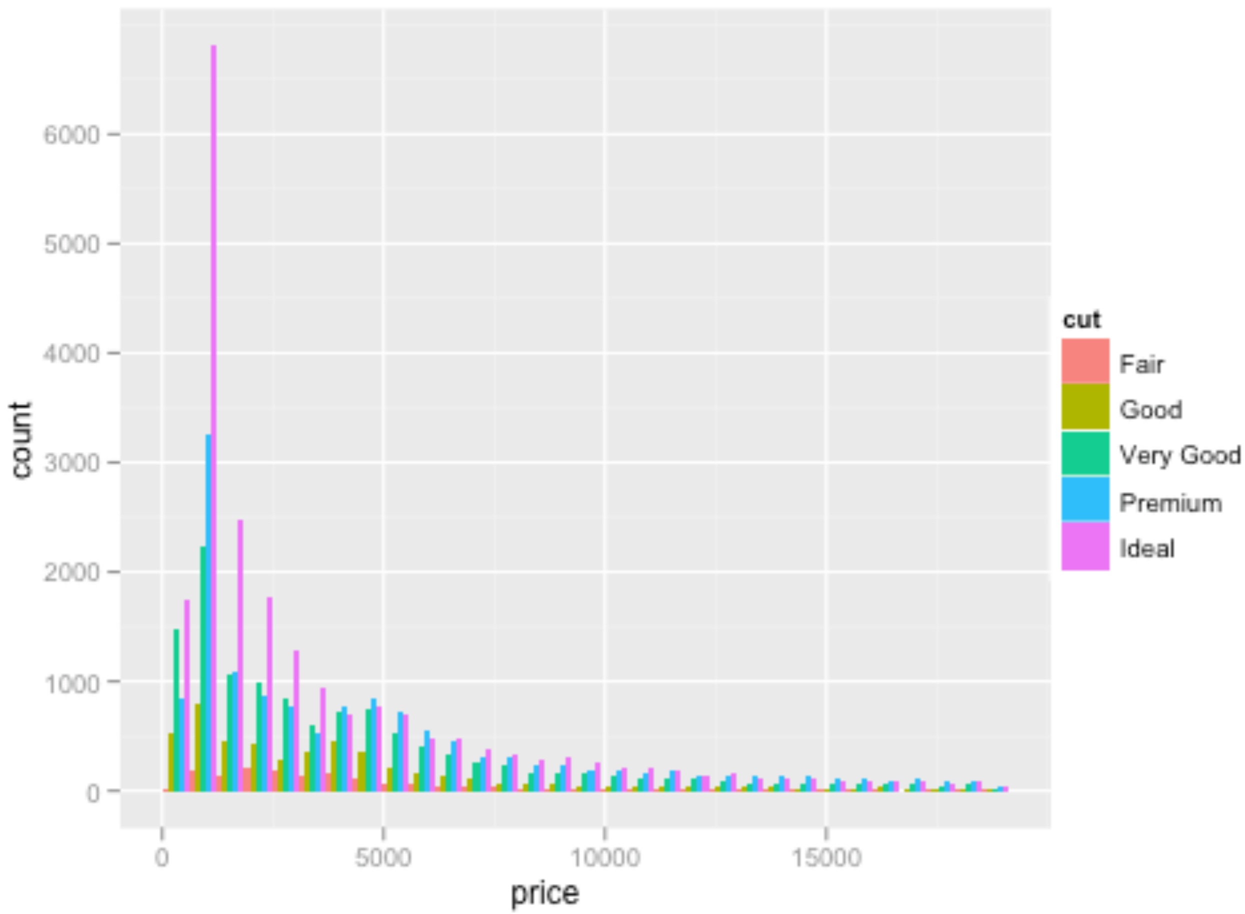
Leland Wilkinson

The Grammar of Graphics

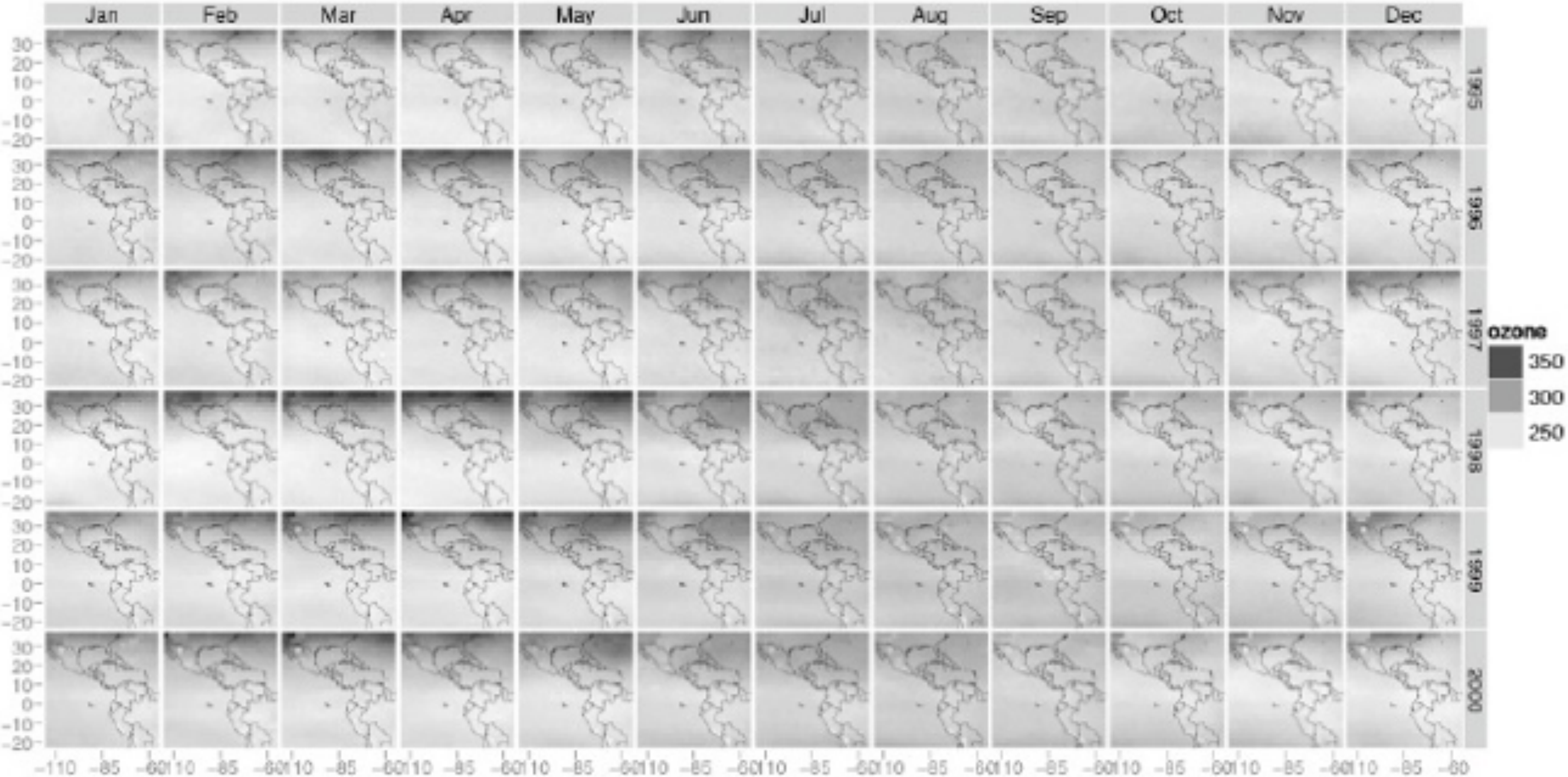
Second Edition

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

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Ease-of-Use

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Ease-of-Use ↑

Expressiveness ↓

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?

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Expressiveness

Ease-of-Use

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VizQL, ggplot2

Visualization Grammars

Protovis, D3.js

Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Processing, OpenGL, Java2D

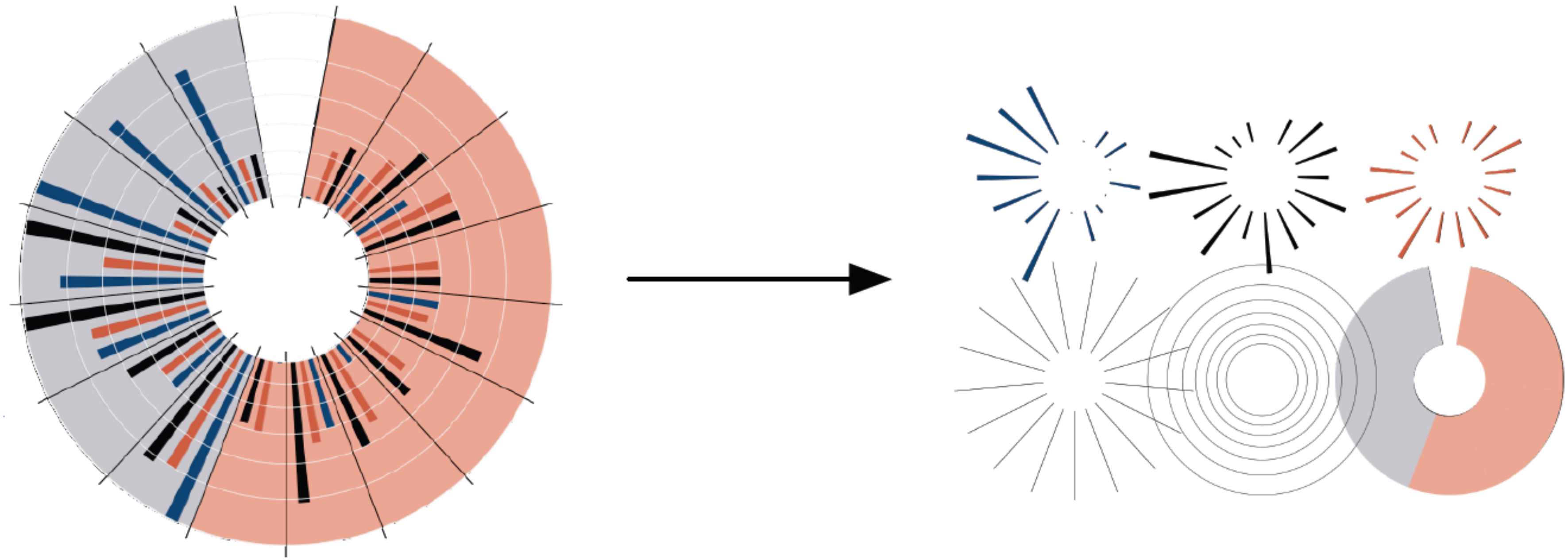
Expressiveness

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**.

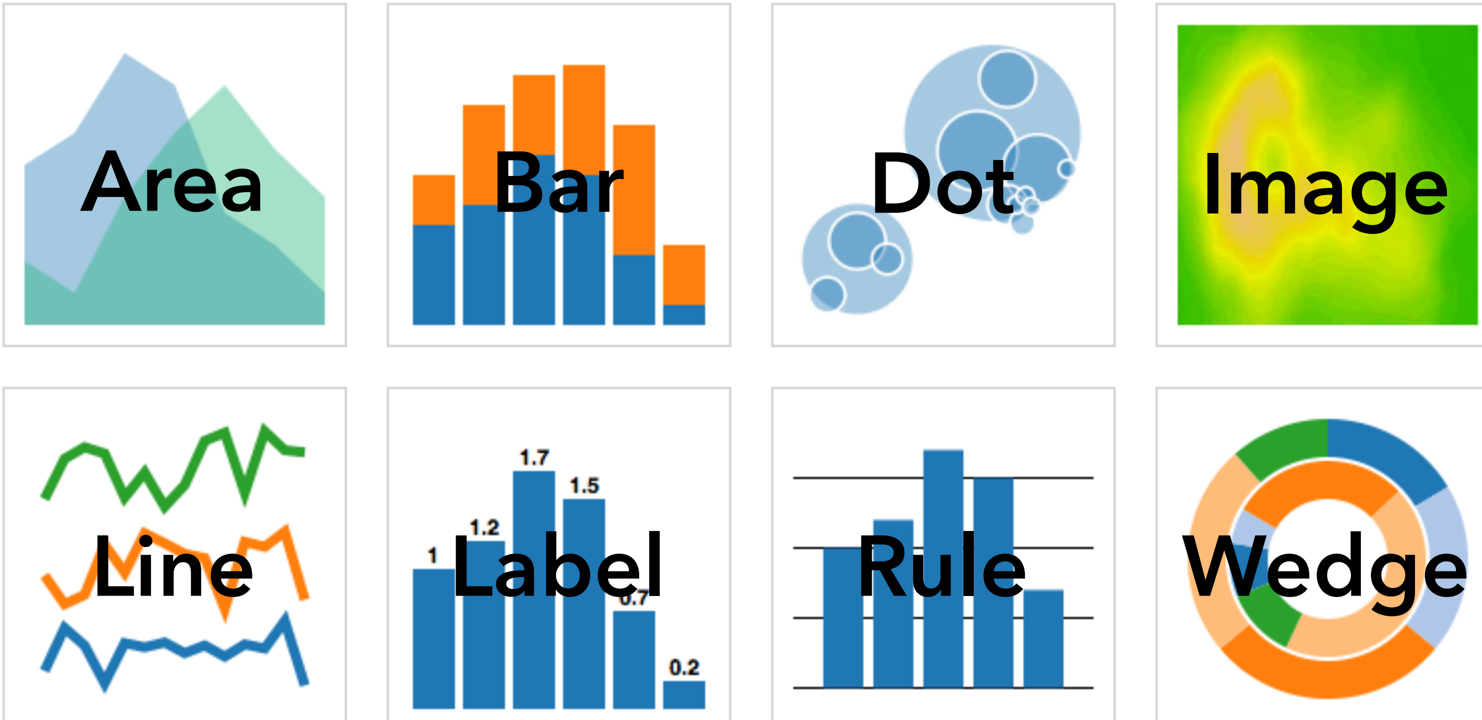
J. W. Tukey, M. B. Wilk
Data Analysis & Statistics, 1965

Protovis: A Grammar for Visualization



A graphic is a composition of data-representative marks.

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



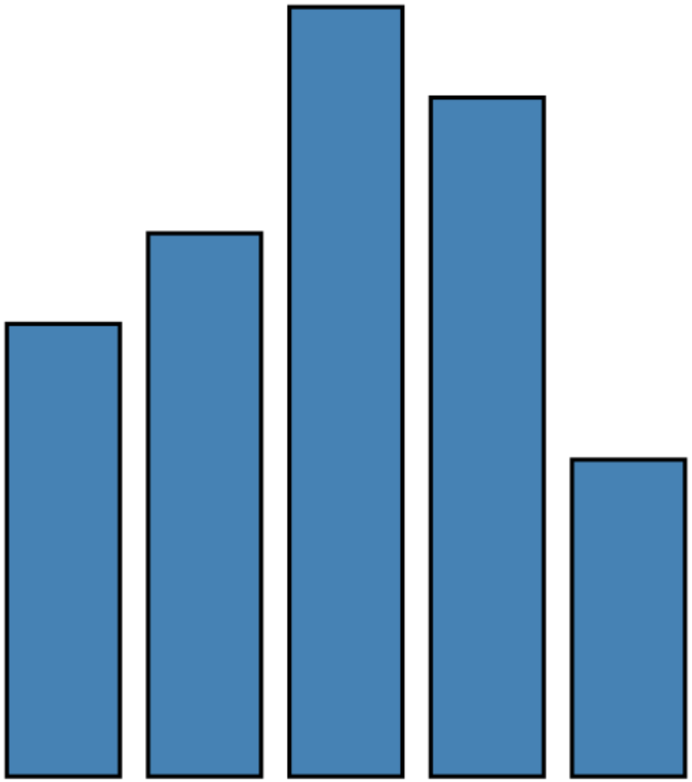
MARKS: Protovis graphical primitives

MARK $\lambda : D \rightarrow R$

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

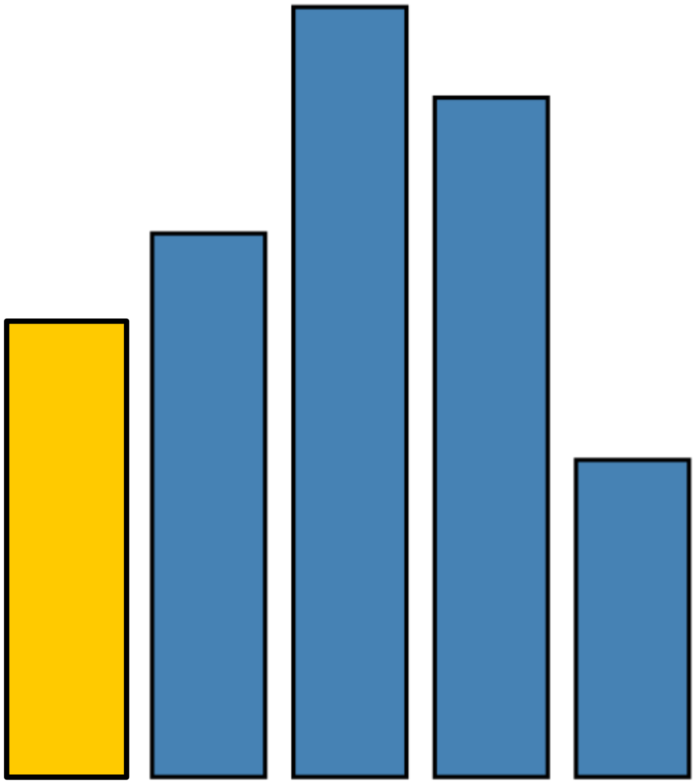
RECT $\lambda : D \rightarrow R$

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				
...	...				



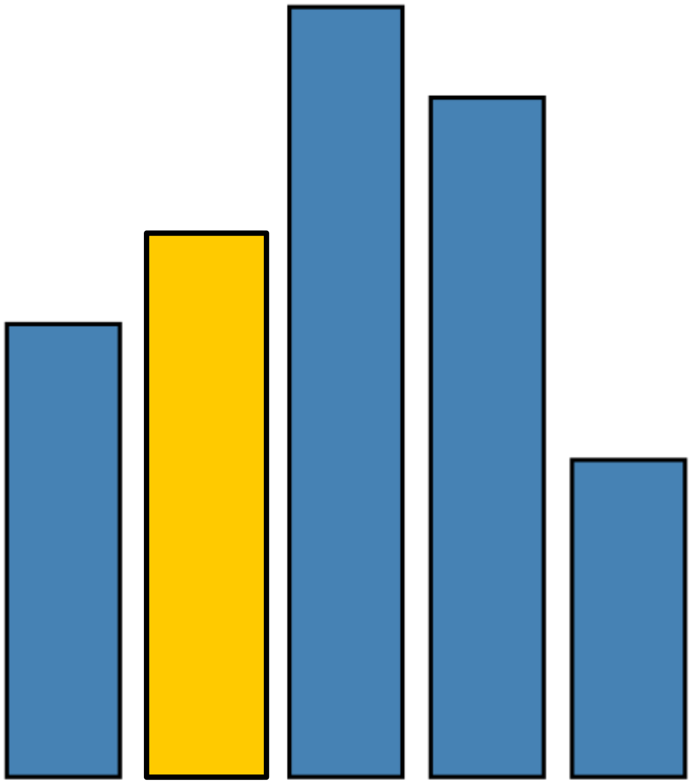
RECT $\lambda : D \rightarrow R$

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				
...	...				



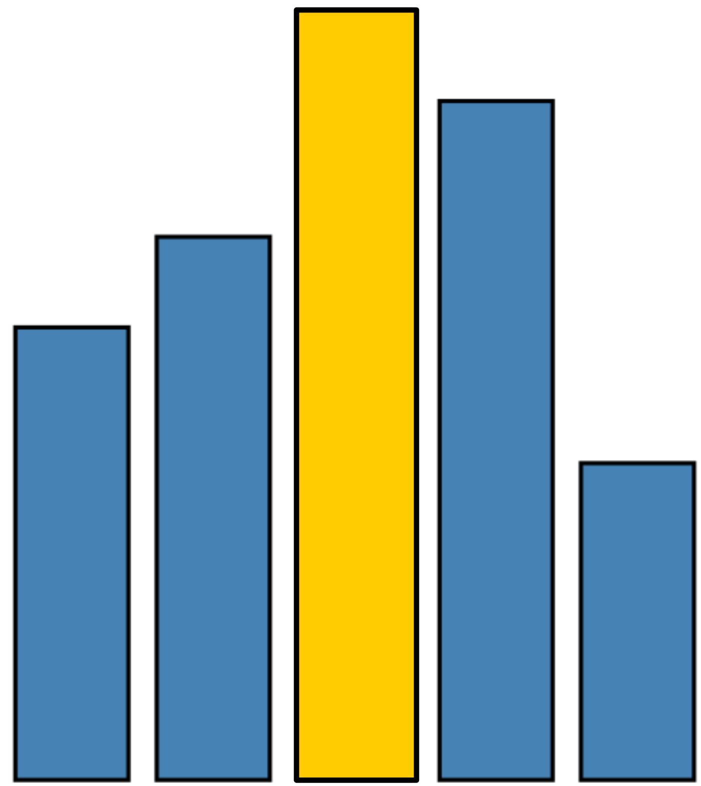
RECT $\lambda : D \rightarrow R$

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				
...	...				



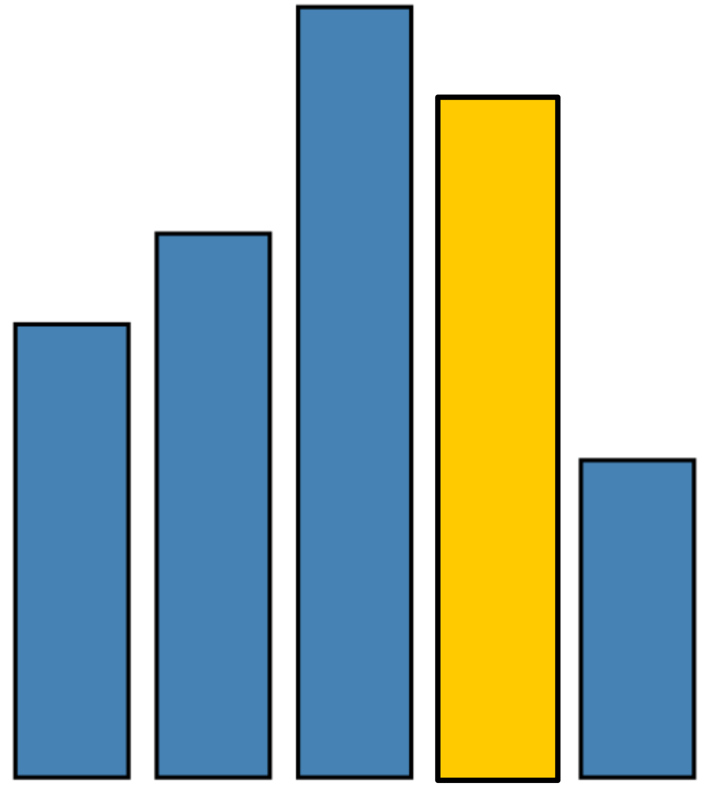
RECT $\lambda : D \rightarrow R$

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				
...	...				



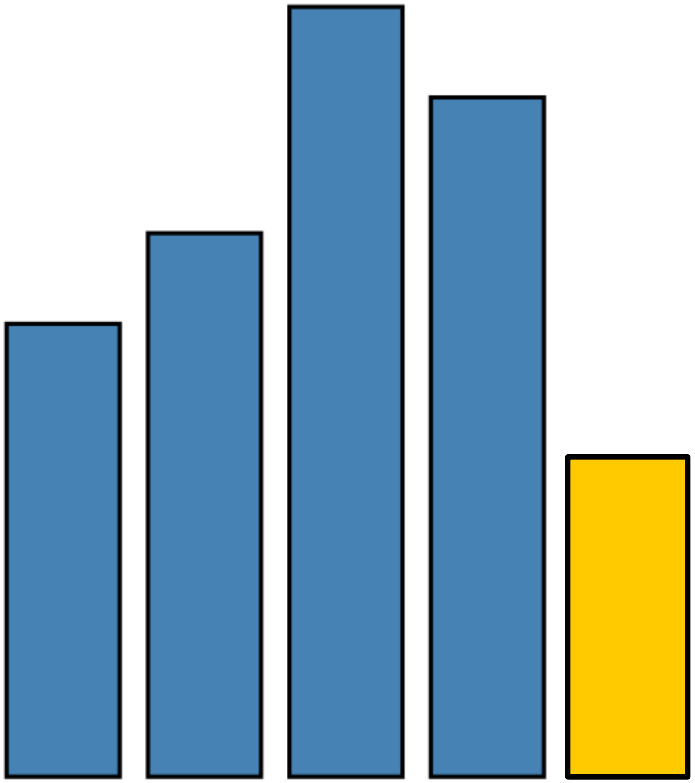
RECT $\lambda : D \rightarrow R$

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				
...	...				



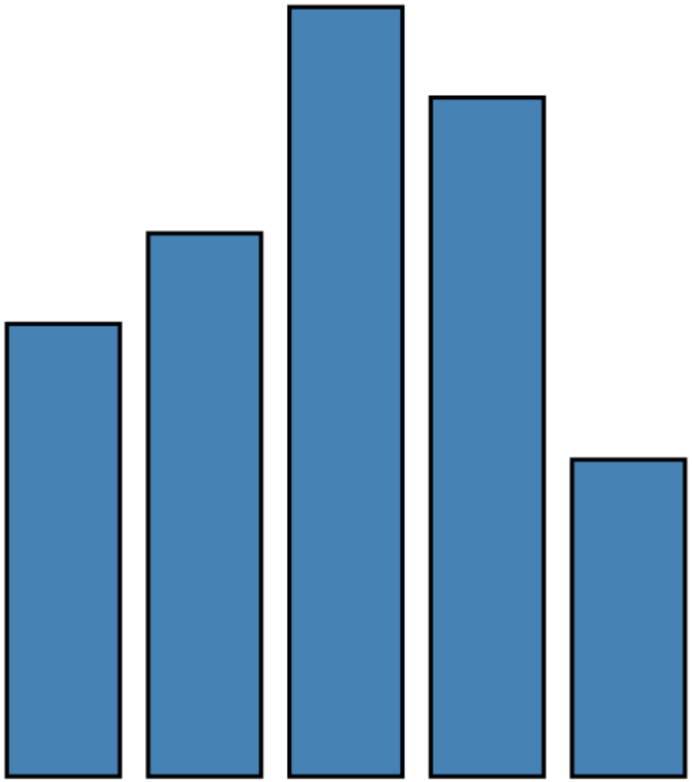
RECT $\lambda : \boldsymbol{D} \rightarrow \boldsymbol{R}$

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				
...	...				

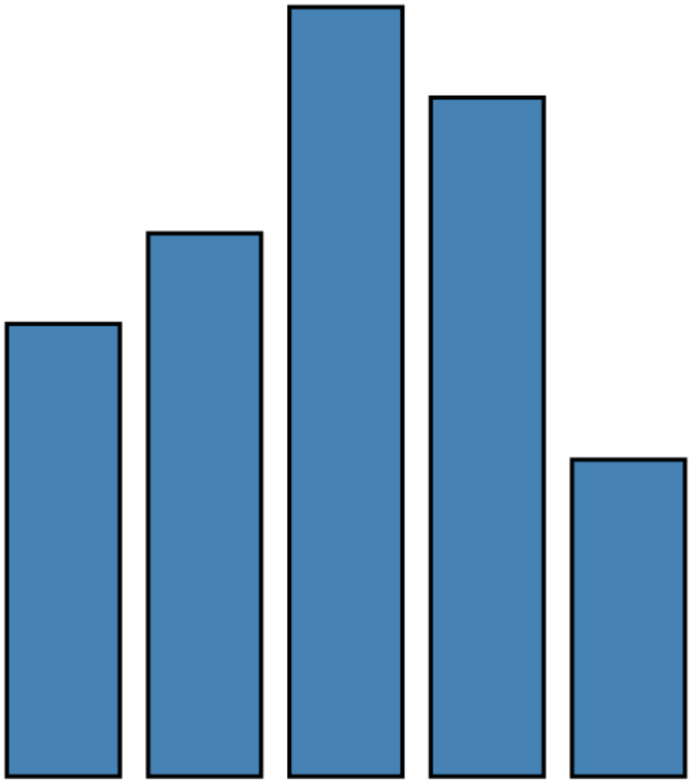


RECT $\lambda : D \rightarrow R$

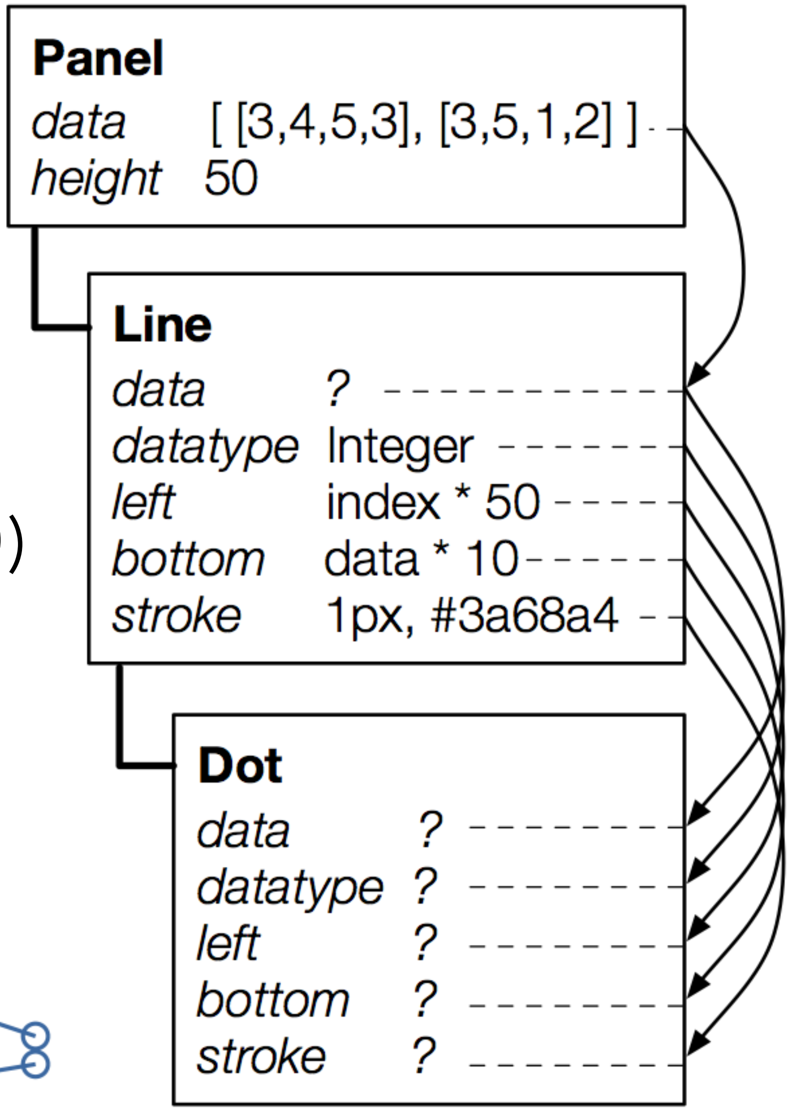
data	1	1.2	1.7	1.5	0.7
visible	true				
left	λ: index * 25				
bottom	0				
width	20				
height	λ: datum * 80				
fillStyle	blue				
strokeStyle	black				
lineWidth	1.5				
...	...				

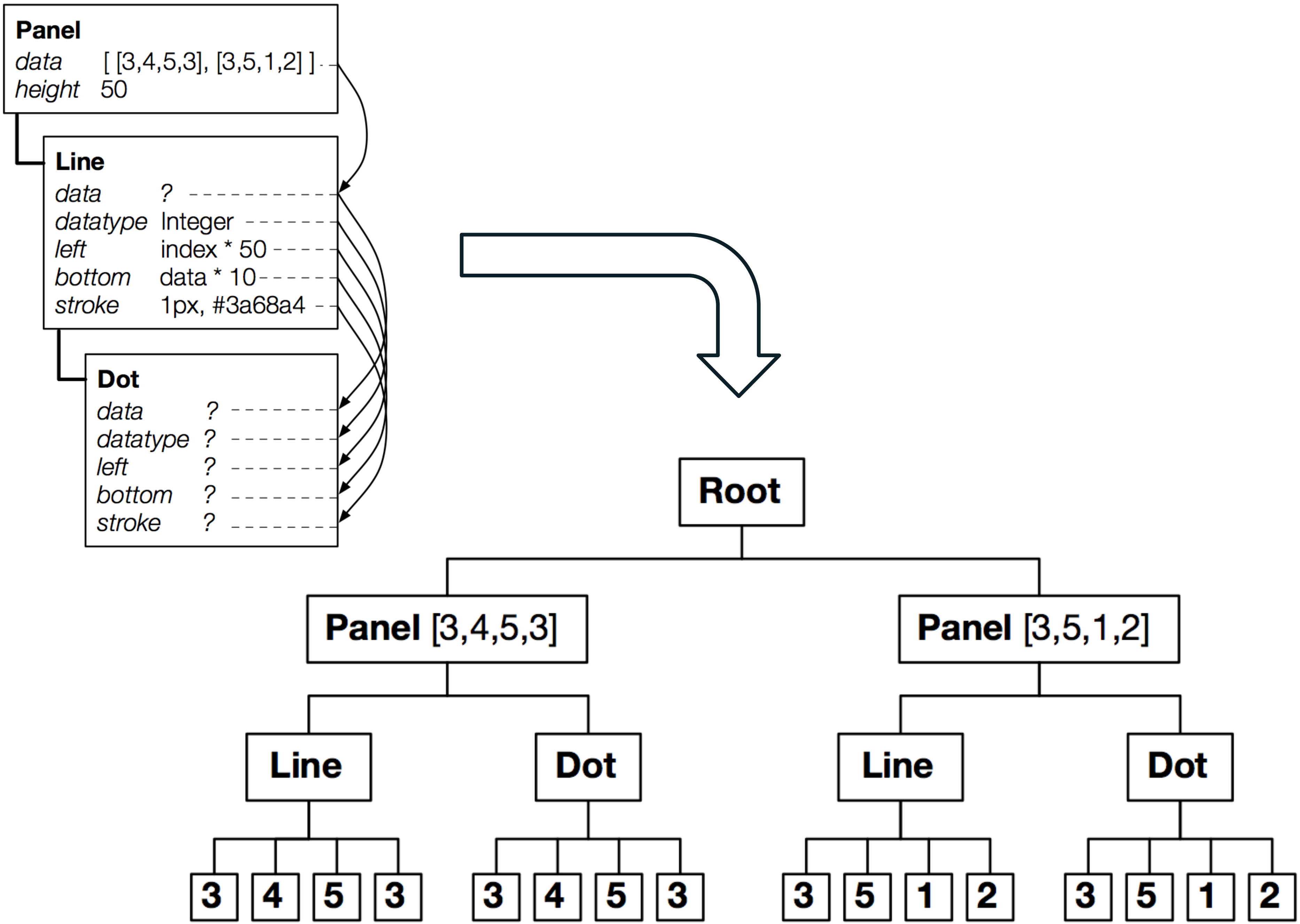


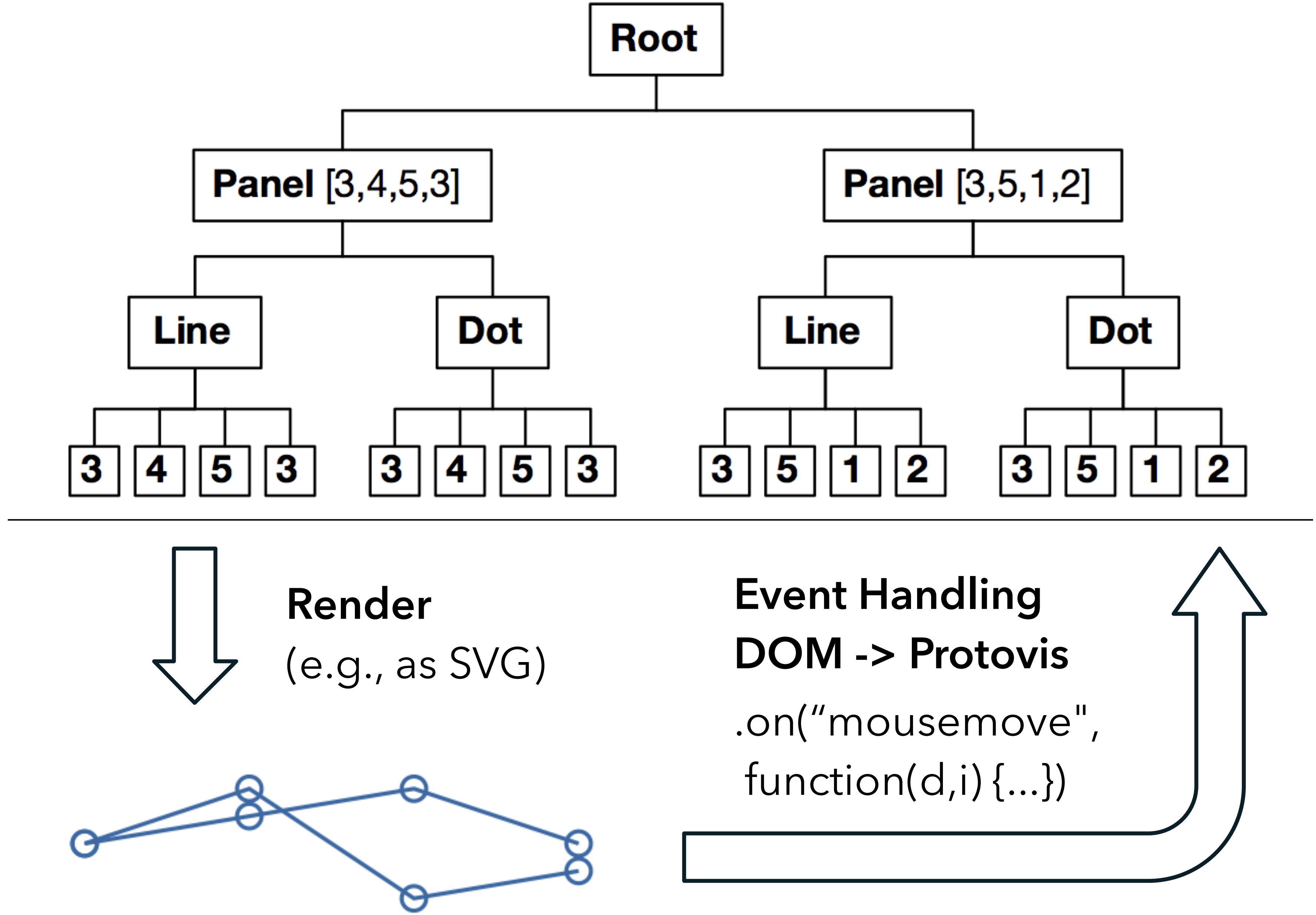
```
var vis = new pv.Panel();
vis.add(pv.Bar)
  .data([1, 1.2, 1.7, 1.5, 0.7])
  .visible(true)
  .left(function(d) this.index * 25);
  .bottom(0)
  .width(20)
  .height(function(d) d * 80)
  .fillStyle(“blue”)
  .strokeStyle(“black”)
  .lineWidth(1.5);
vis.render();
```

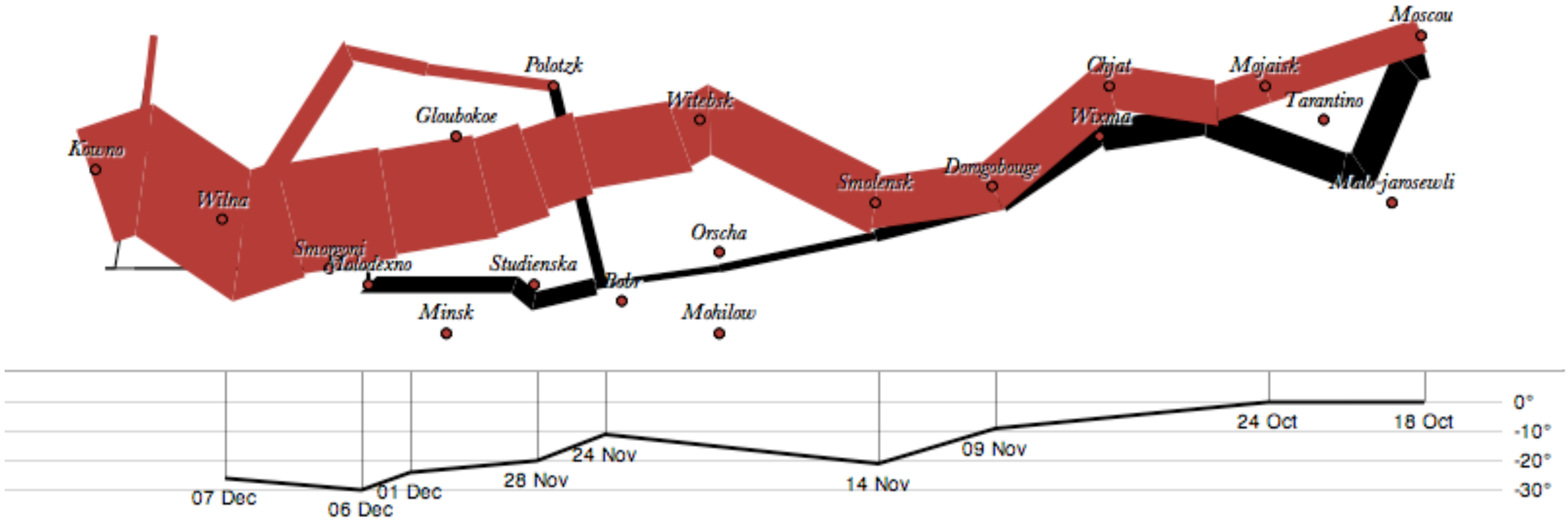


```
var data = [[3,4,5,3], [3,5,1,2]];
var vis = new pv.Panel()
  .data(data)
  .height(50);
vis.add(pv.Line)
  .left(function(d) this.index * 50)
  .bottom(function(d) d * 10)
  .strokeStyle("#3a68a4")
.add(pv.Dot);
vis.render();
```



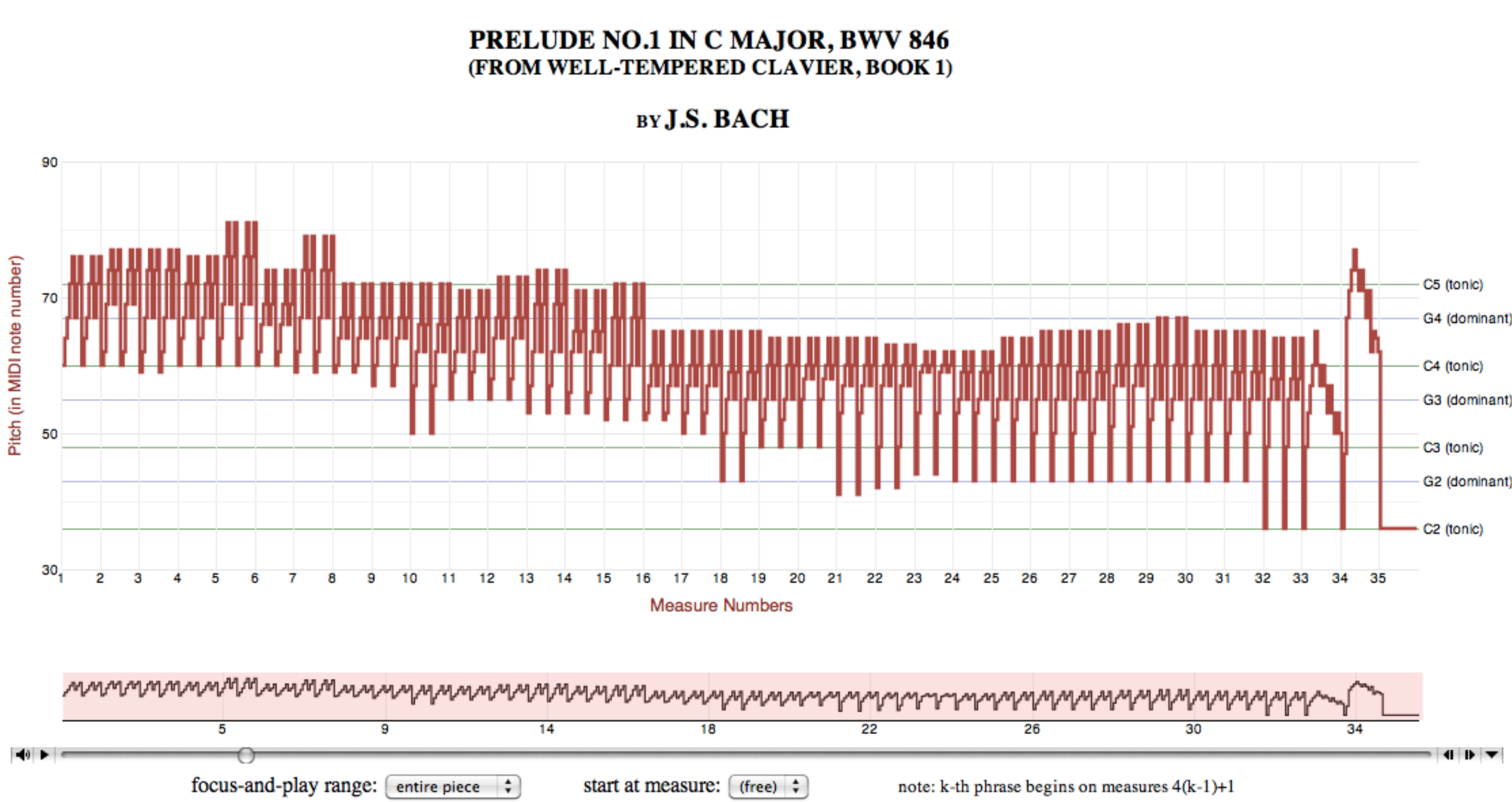

Panel
data [[3,4,5,3], [3,5,1,2]]
height 50
Line
data ?
datatype Integer
left index * 50
bottom data * 10
stroke 1px, #3a68a4
Dot
data ?
datatype ?
left ?
bottom ?
stroke ?
Root
Panel [3,4,5,3]
Panel [3,5,1,2]
Line
Dot
Line
Dot
3 4 5 3
3 4 5 3
3 5 1 2
3 5 1 2


Root
Panel [3,4,5,3]
Panel [3,5,1,2]
Line
Dot
Line
Dot
3
4
5
3
3
4
5
3
3
5
1
2
3
5
1
2
Render
(e.g., as SVG)
Event Handling
DOM -> Protovis
.on("mousemove",
function(d,i) {...})

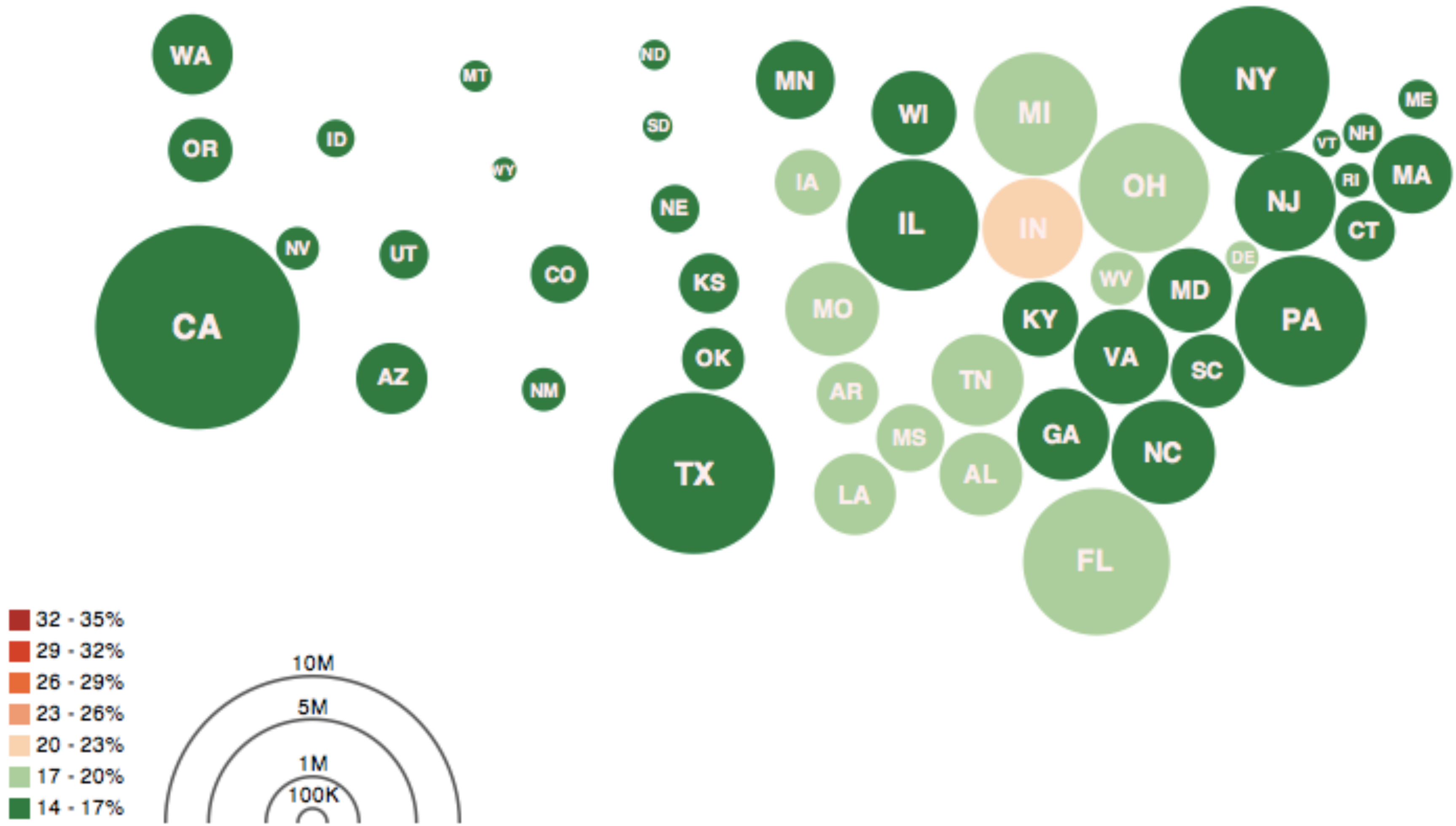



```
var army = pv.nest(napoleon.army, "dir", "group“);
var vis = new pv.Panel();

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

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

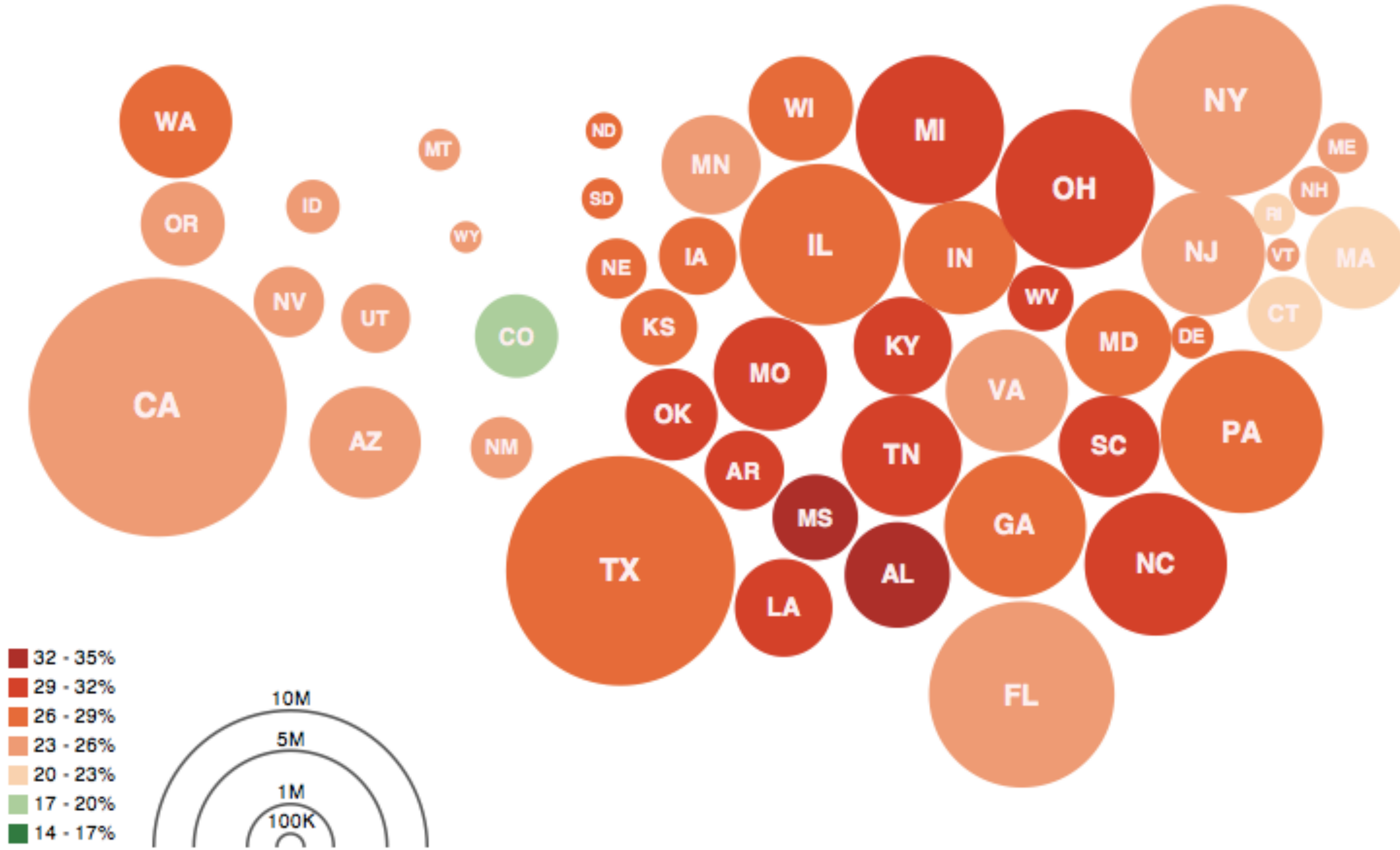
```
vis.add(pv.Rule).data([0,-10,-20,-30])
   .top(function(d) 300 - 2*d - 0.5).left(200).right(150)
   .lineWidth(1).strokeStyle("#ccc")
   .anchor("right").add(pv.Label)
     .font("italic 10px Georgia")
     .text(function(d) d+"°").textBaseline("center");

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



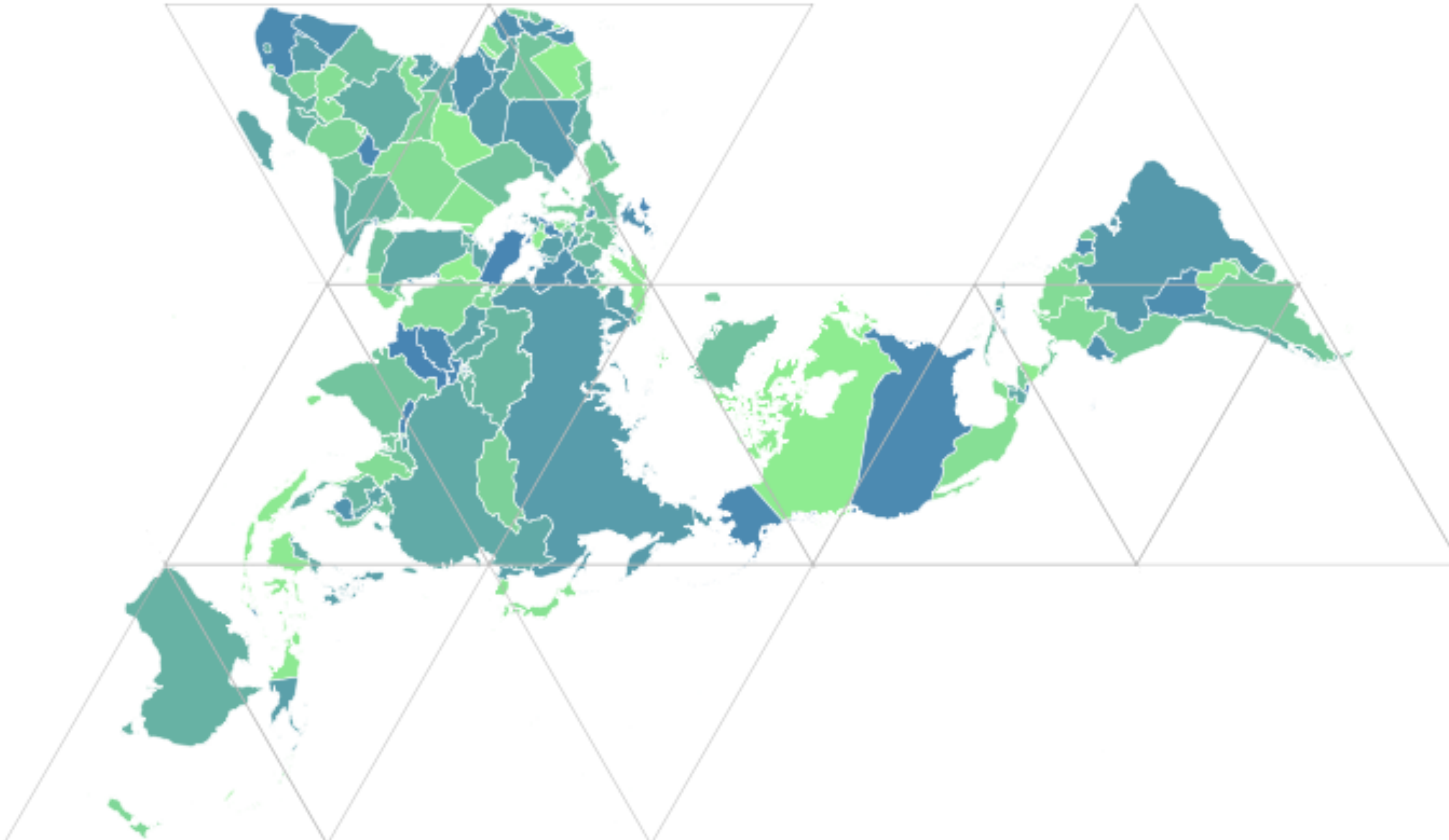
Bach's Prelude #1 in C Major | Jieun Oh



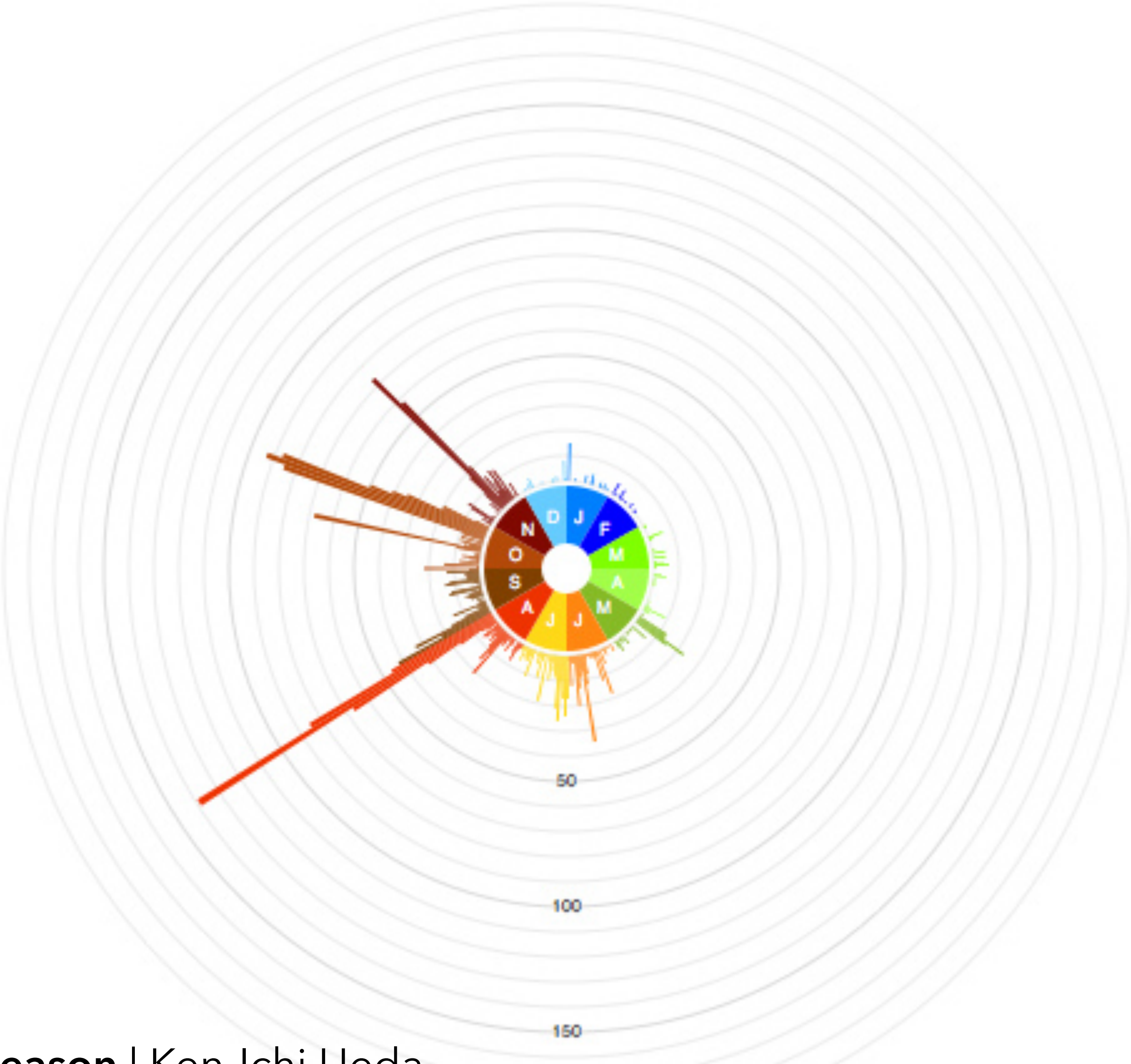
Obesity Map | Vadim Ogievetsky



Obesity Map | Vadim Ogievetsky

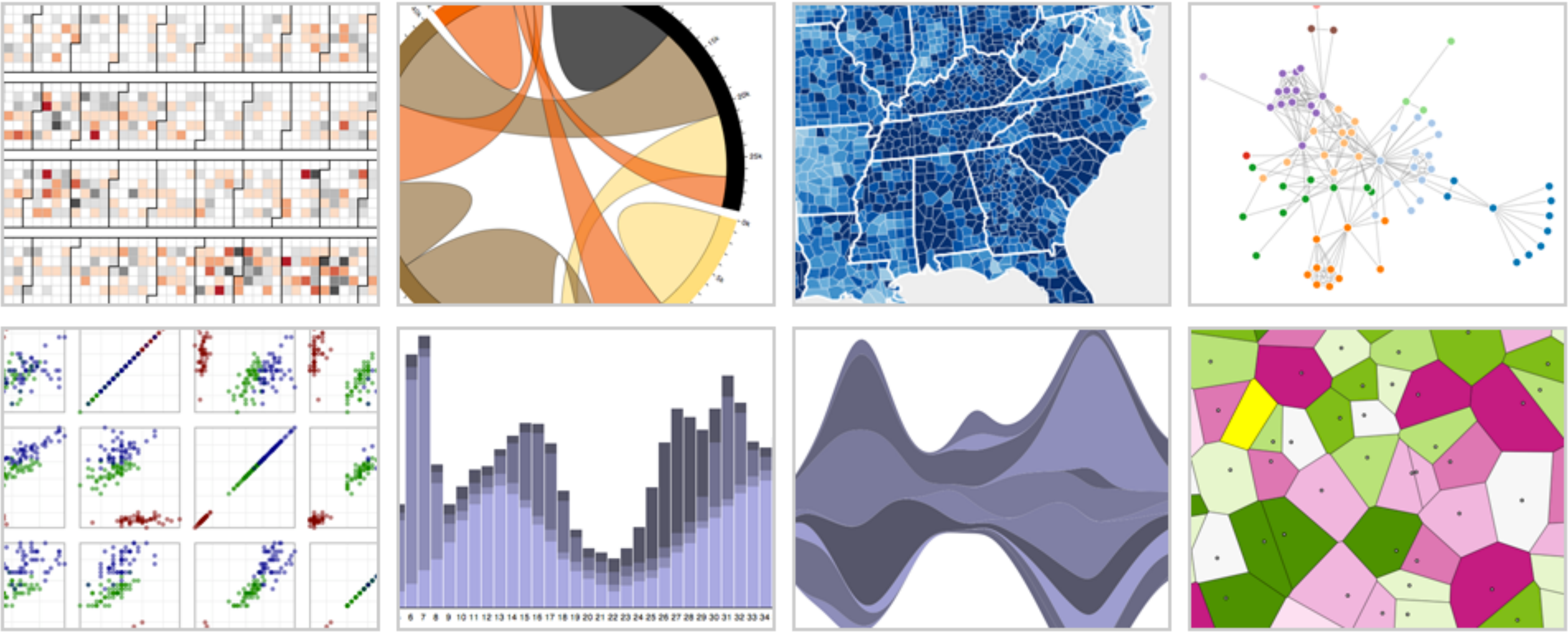


Dymaxion Maps | Vadim Ogievetsky



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

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- 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

Selection + Data Join

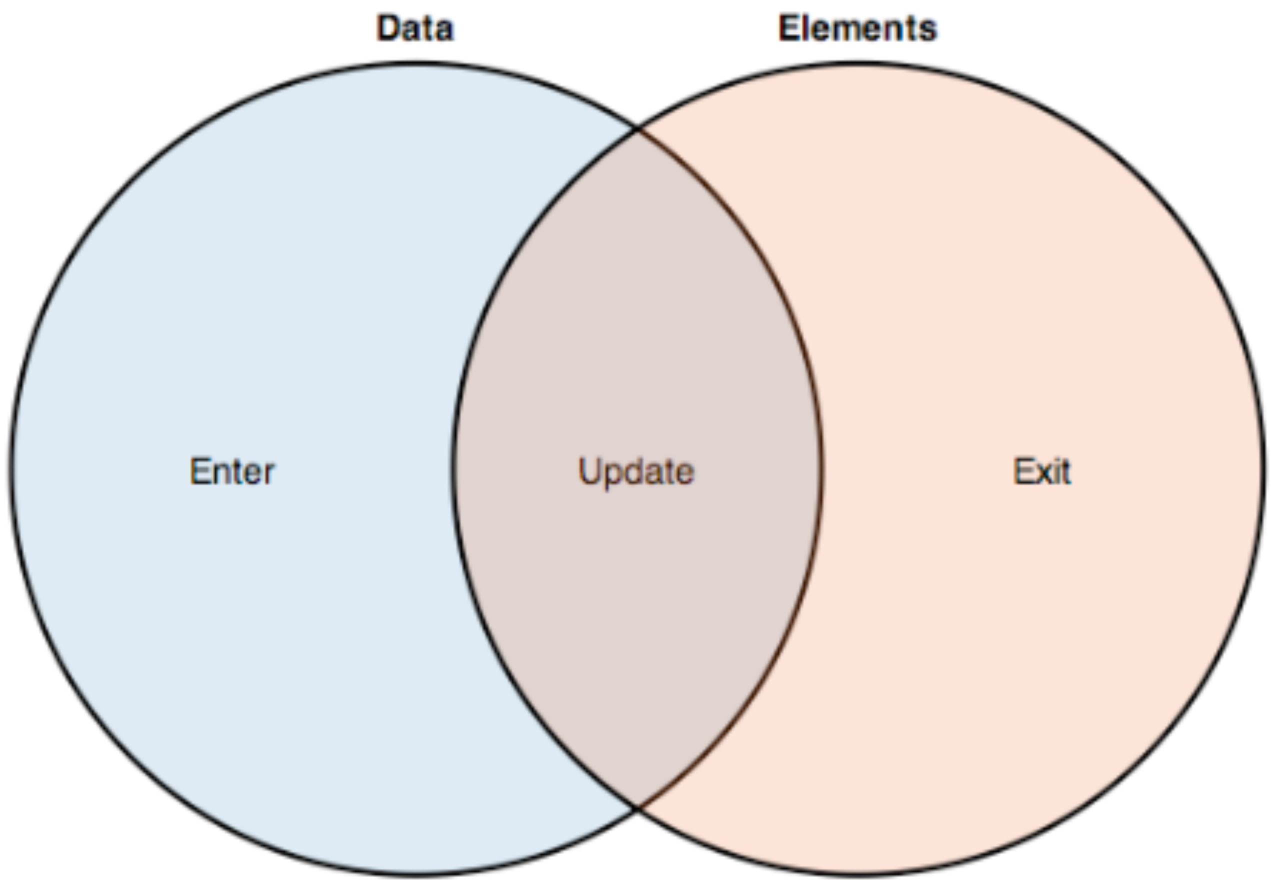


Chart Typologies

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

Ease-of-Use

Expressiveness

Administrivia

A2: Exploratory Data Analysis

Use visualization software to form & answer questions

First steps:

Step 1: Pick domain & data

Step 2: Pose questions

Step 3: Profile the data

Iterate as needed

Create visualizations

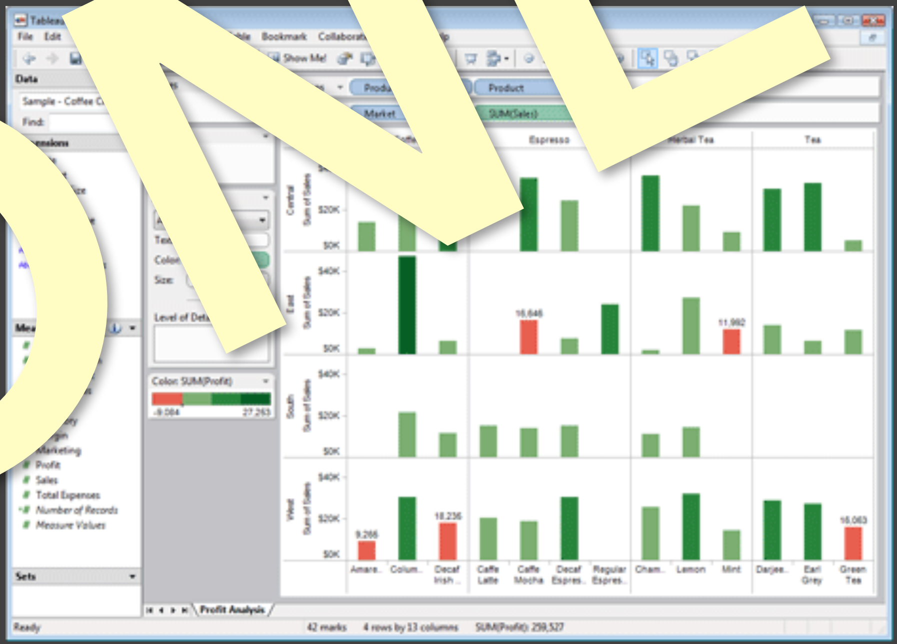
Interact with data

Refine your questions

Make a notebook

Keep record of your analysis

Prepare a final graphic and caption



Due by 5:00pm

Friday, April 17

DONE

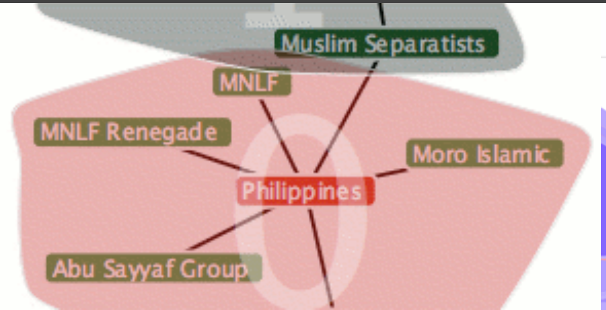
A3: Interactive Visualization

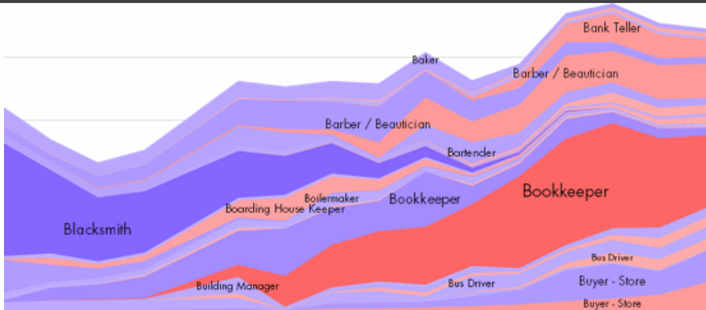
Create an interactive visualization application. Choose a data domain and an appropriate visualization technique.

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

You should work in groups of 2.

Due by *5pm* on **Monday, May 4**





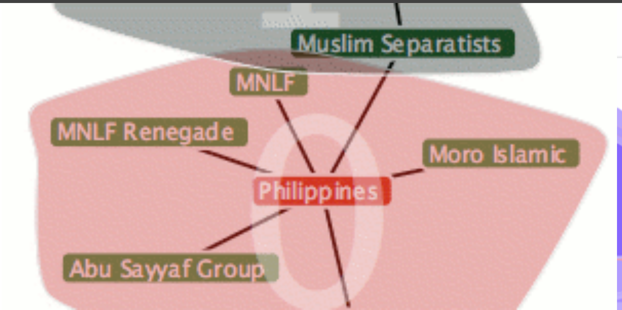
A3: Project Partners

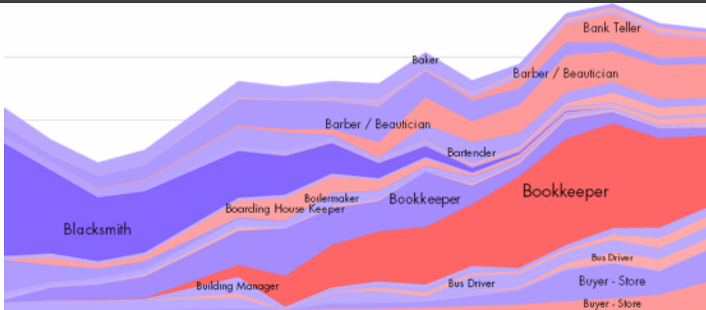
For A3, you should work in **groups of 2-3**.

If you do not have a partner, you should:

Use the facilities on Canvas

Stay after class to meet potential partners



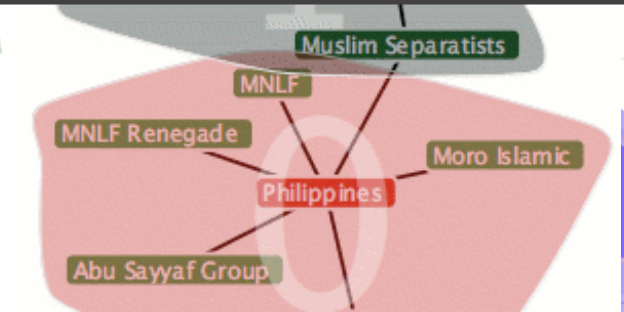


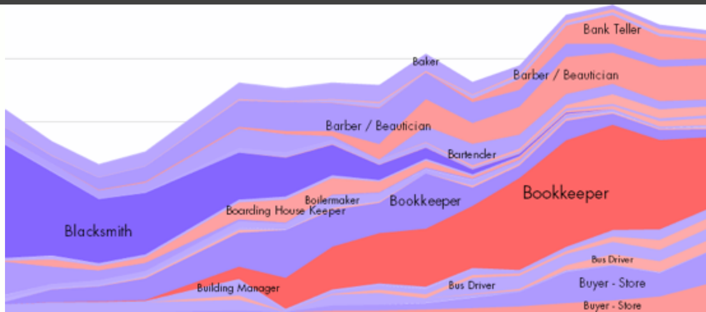
Assignment 3 Tips

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. Keep the design clean.

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





A Visualization Tool Stack

Chart Typologies
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What is a Declarative Language?

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

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

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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); })
```


ODAY'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.

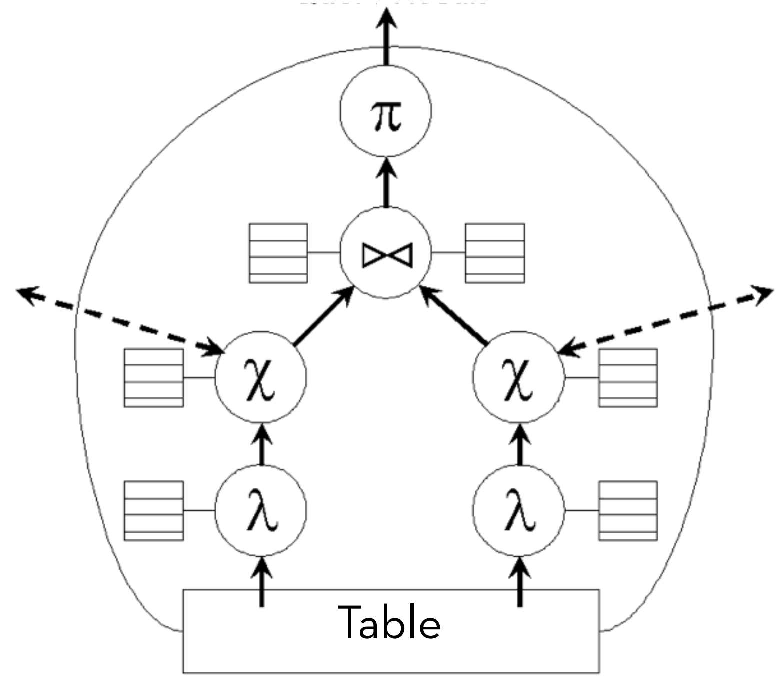
- Brooks: No Second Thoughts | Comments (200)
- Herbert: The Corrosion of America
- Cohen: Turkey Steps Out
- Editorial: Mortgage Mess
- Bloggingheads: Jon Stewart's Power

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/
    1b1a17550Q2F,.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

Chart Typologies

Excel, Many Eyes, Google Charts

Charting Tools

Visual Analysis Grammars

VizQL, ggplot2

Visualization Grammars

Protovis, D3.js

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

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Interactive Data Exploration

Tableau, ***Lyra, Polestar, Voyager***

Graphical Interfaces

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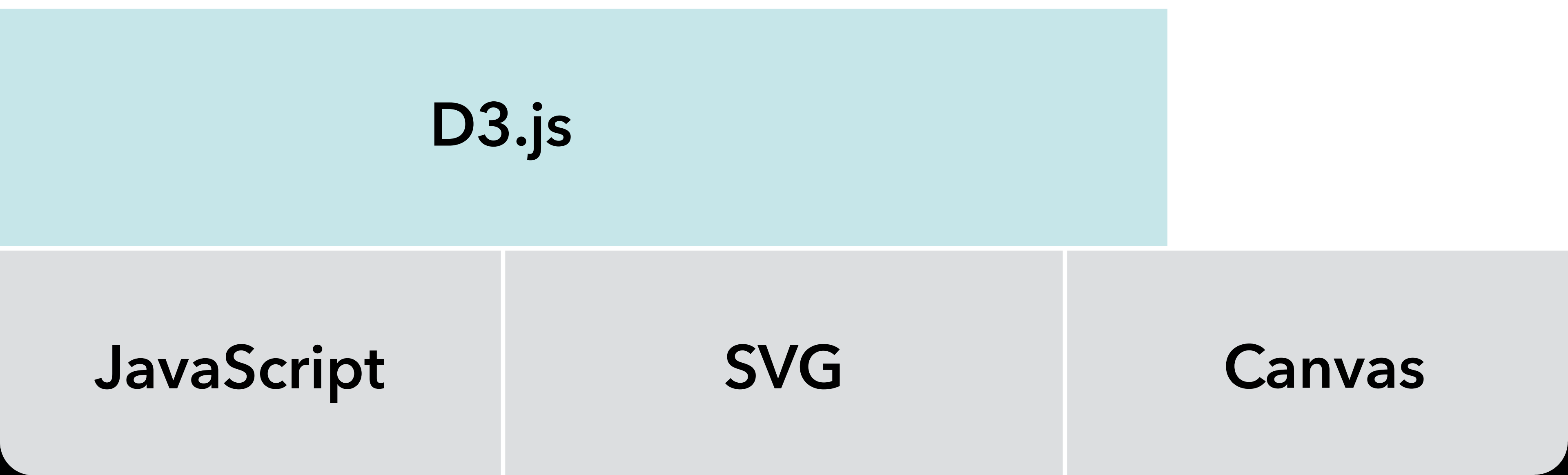
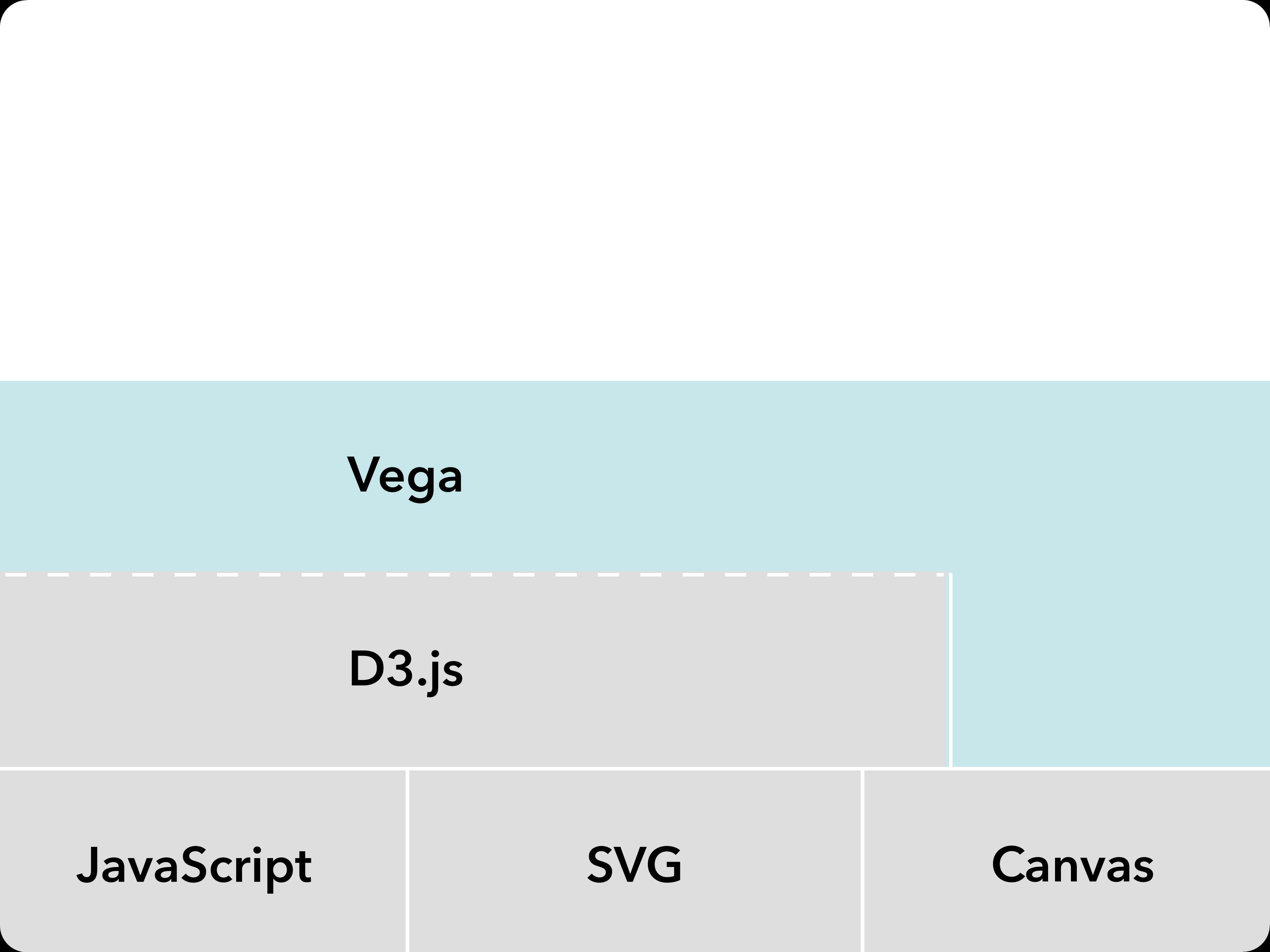
JavaScript	SVG	Canvas


D3.js
JavaScript
SVG
Canvas


Vega
D3.js
JavaScript
SVG
Canvas

Visualization Grammar

Visualization Grammar

Data Input data to visualize

Visualization Grammar

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

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

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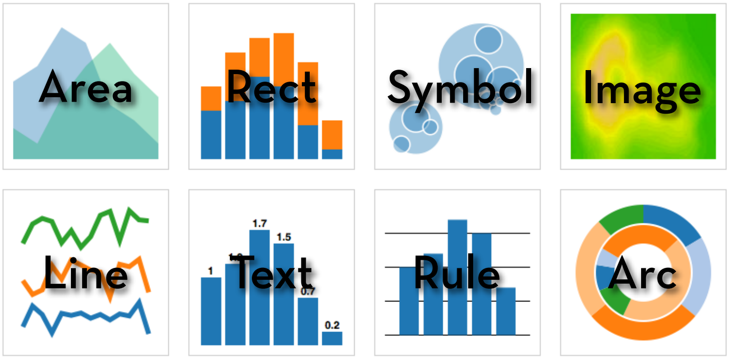
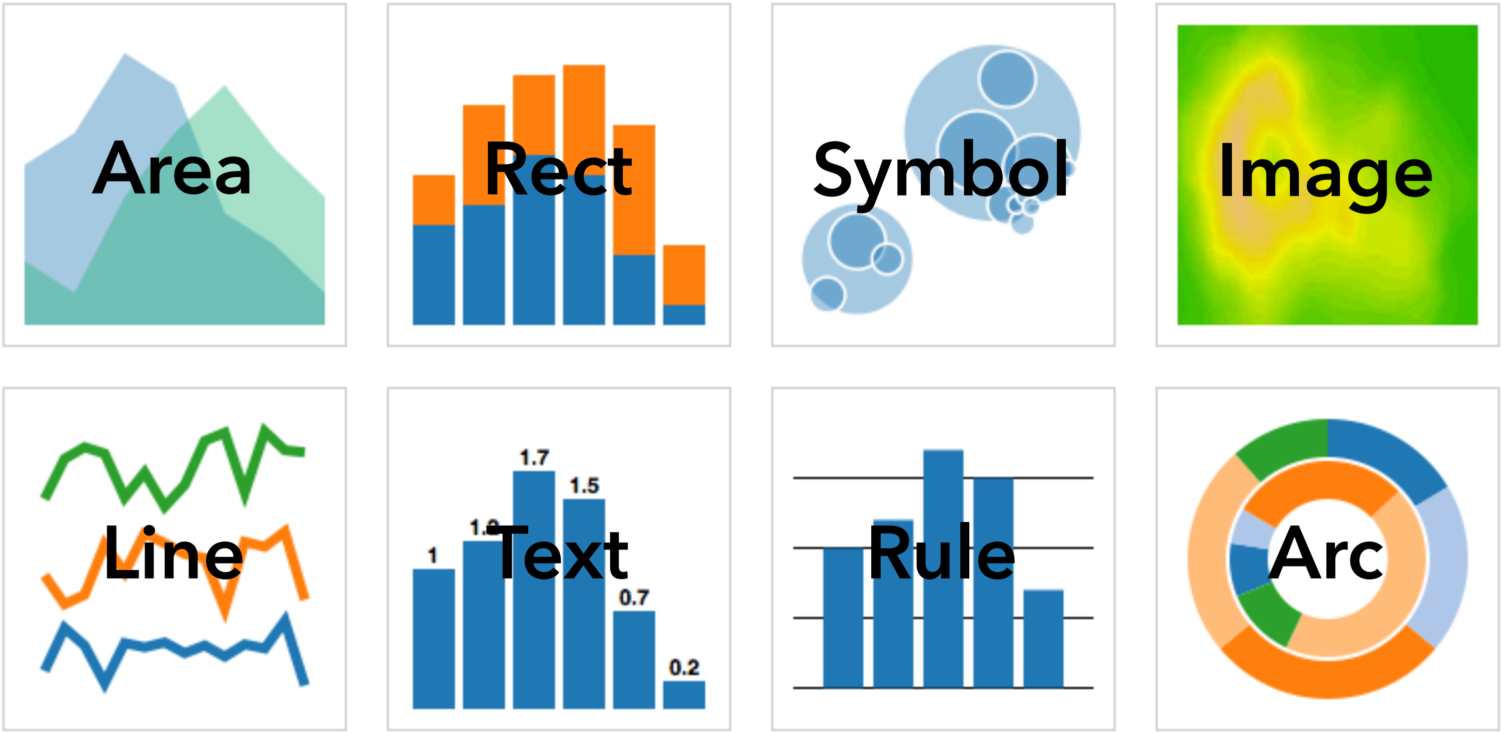
Guides	Axes & legends visualize scales

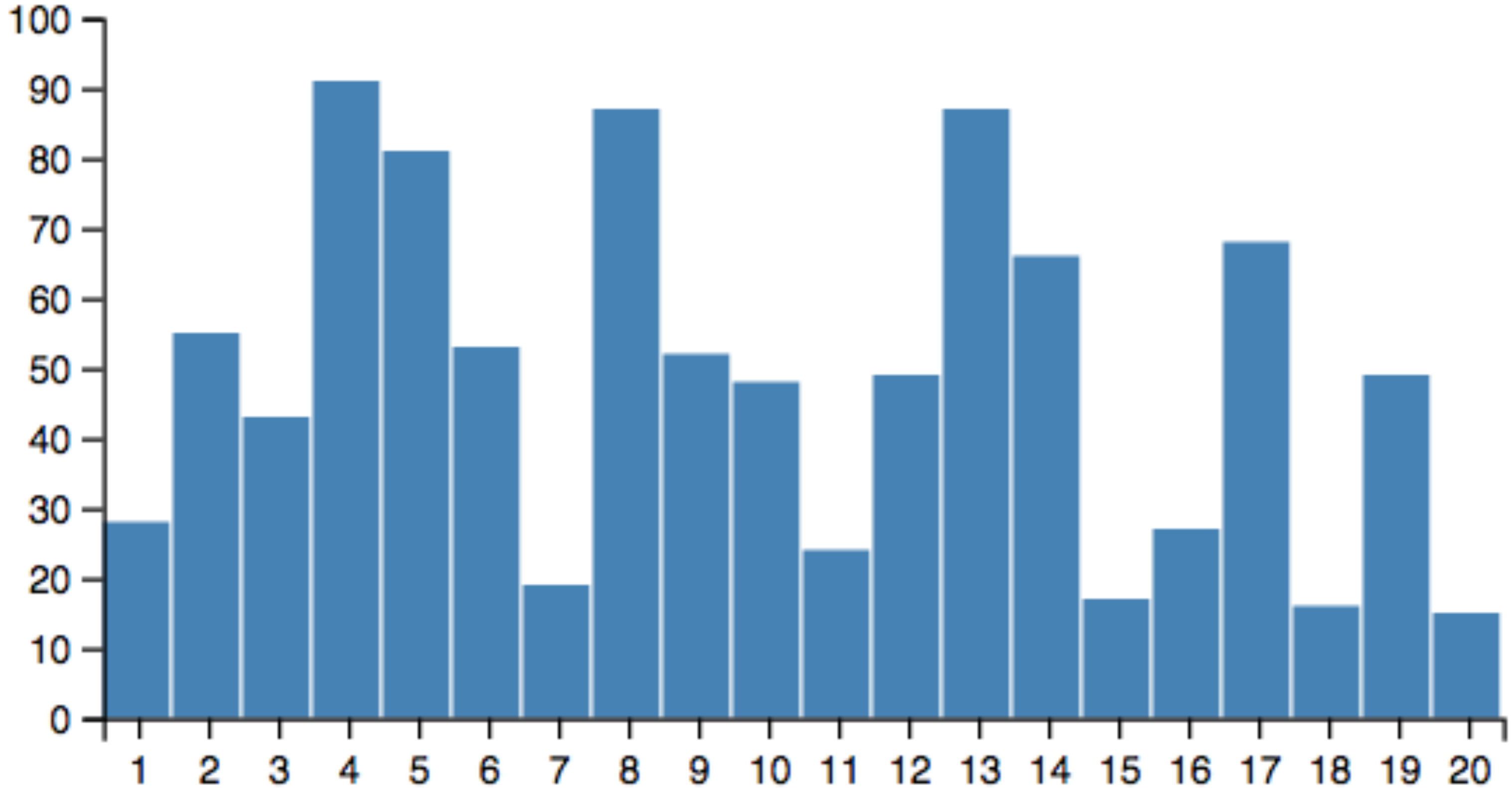
Visualization Grammar

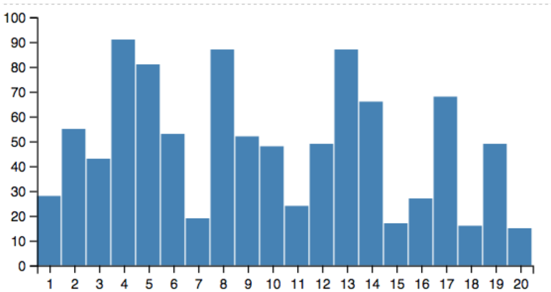
Data	Input data to visualize
Transforms	Grouping, stats, projection, layout
Scales	Map data values to visual values
Guides	Axes & legends visualize scales
Marks	Data-representative graphics





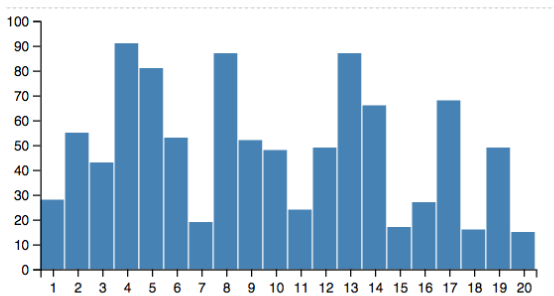
MARKS: Graphical Primitives


100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20



100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

```
{
  "width": 400, "height": 200,
  "data": [
    {"name": "table", "url": "/data/sample.json"}
  ],
  "scales": [
    {
      "name": "x","type": "ordinal",
      "range": "width",
      "domain": {"data": "table", "field": "x"}
    },
    {
      "name": "y",
      "range": "height", "nice": true,
      "domain": {"data": "table", "field": "y"}
    }
  ],
  "axes": [
    {"type": "x", "scale": "x"},
    {"type": "y", "scale": "y"}
  ],
  "marks": [{
    "type": "rect",
    "from": {"data": "table"},
    "properties": {
      "enter": {
        "x": {"scale": "x", "field": "x"},
        "width": {"scale": "x", "band": true, "offset": -1},
        "y": {"scale": "y", "field": "y"},
        "y2": {"scale": "y", "value": 0},
        "fill": {"value": "steelblue"}
      }
    }
  }]
}
```



Data + Transforms

```
{
  "width": 400, "height": 200,
  "data": [
    {"name": "table", "url": "/data/sample.json"}
  ],
  "scales": [
    {
      "name": "x","type": "ordinal",
      "range": "width",
      "domain": {"data": "table", "field": "x"}
    },
    {
      "name": "y",
      "range": "height", "nice": true,
      "domain": {"data": "table", "field": "y"}
    }
  ],
  "axes": [
    {"type": "x", "scale": "x"},
    {"type": "y", "scale": "y"}
  ],
  "marks": [{
    "type": "rect",
    "from": {"data": "table"},
    "properties": {
      "enter": {
        "x": {"scale": "x", "field": "x"},
        "width": {"scale": "x", "band": true, "offset": -1},
        "y": {"scale": "y", "field": "y"},
        "y2": {"scale": "y", "value": 0},
        "fill": {"value": "steelblue"}
      }
    }
  }]
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```

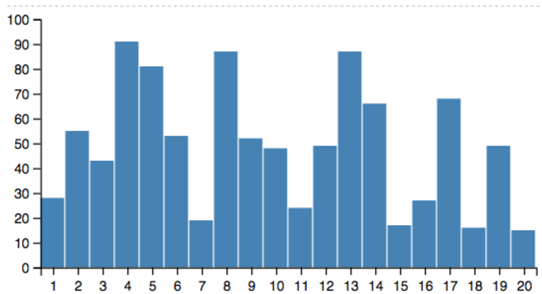

```
{
  "width": 400, "height": 200,
  "data": [
    {"name": "table", "url": "/data/sample.json"}
  ],
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    {
      "name": "x","type": "ordinal",
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      "domain": {"data": "table", "field": "x"}
    },
    {
      "name": "y",
      "range": "height", "nice": true,
      "domain": {"data": "table", "field": "y"}
    }
  ],
  "axes": [
    {"type": "x", "scale": "x"},
    {"type": "y", "scale": "y"}
  ],
  "marks": [{
    "type": "rect",
    "from": {"data": "table"},
    "properties": {
      "enter": {
        "x": {"scale": "x", "field": "x"},
        "width": {"scale": "x", "band": true, "offset": -1},
        "y": {"scale": "y", "field": "y"},
        "y2": {"scale": "y", "value": 0},
        "fill": {"value": "steelblue"}
      }
    }
  }]
}
```
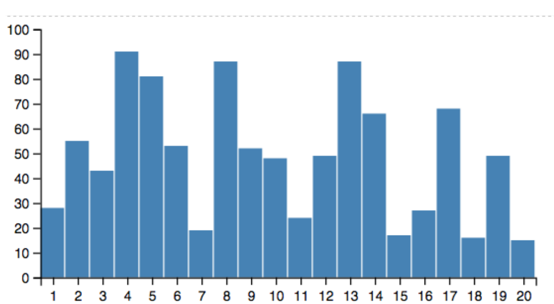

Data + Transforms

Scales

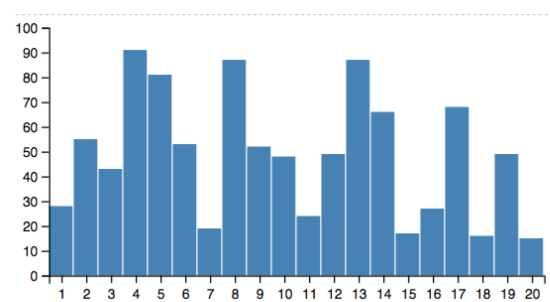


```
{
  "width": 400, "height": 200,
  "data": [
    {"name": "table", "url": "/data/sample.json"}
  ],
  "scales": [
    {
      "name": "x","type": "ordinal",
      "range": "width",
      "domain": {"data": "table", "field": "x"}
    },
    {
      "name": "y",
      "range": "height", "nice": true,
      "domain": {"data": "table", "field": "y"}
    }
  ],
  "axes": [
    {"type": "x", "scale": "x"},
    {"type": "y", "scale": "y"}
  ],
  "marks": [{
    "type": "rect",
    "from": {"data": "table"},
    "properties": {
      "enter": {
        "x": {"scale": "x", "field": "x"},
        "width": {"scale": "x", "band": true, "offset": -1},
        "y": {"scale": "y", "field": "y"},
        "y2": {"scale": "y", "value": 0},
        "fill": {"value": "steelblue"}
      }
    }
  }]
}
```

Data + Transforms

Scales

Guides



```
{
  "width": 400, "height": 200,
  "data": [
    {"name": "table", "url": "/data/sample.json"}
  ],
  "scales": [
    {
      "name": "x","type": "ordinal",
      "range": "width",
      "domain": {"data": "table", "field": "x"}
    },
    {
      "name": "y",
      "range": "height", "nice": true,
      "domain": {"data": "table", "field": "y"}
    }
  ],
  "axes": [
    {"type": "x", "scale": "x"},
    {"type": "y", "scale": "y"}
  ],
  "marks": [{
    "type": "rect",
    "from": {"data": "table"},
    "properties": {
      "enter": {
        "x": {"scale": "x", "field": "x"},
        "width": {"scale": "x", "band": true, "offset": -1},
        "y": {"scale": "y", "field": "y"},
        "y2": {"scale": "y", "value": 0},
        "fill": {"value": "steelblue"}
      }
    }
  }]
}
```

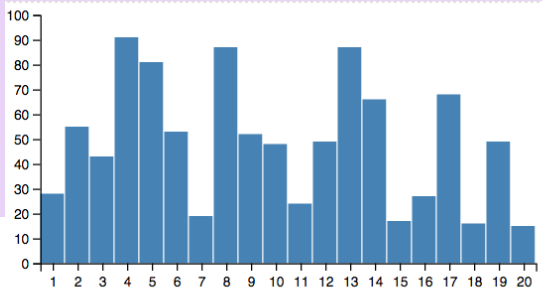
Data + Transforms

Scales

Guides

(Data + Transforms)

Marks



vega

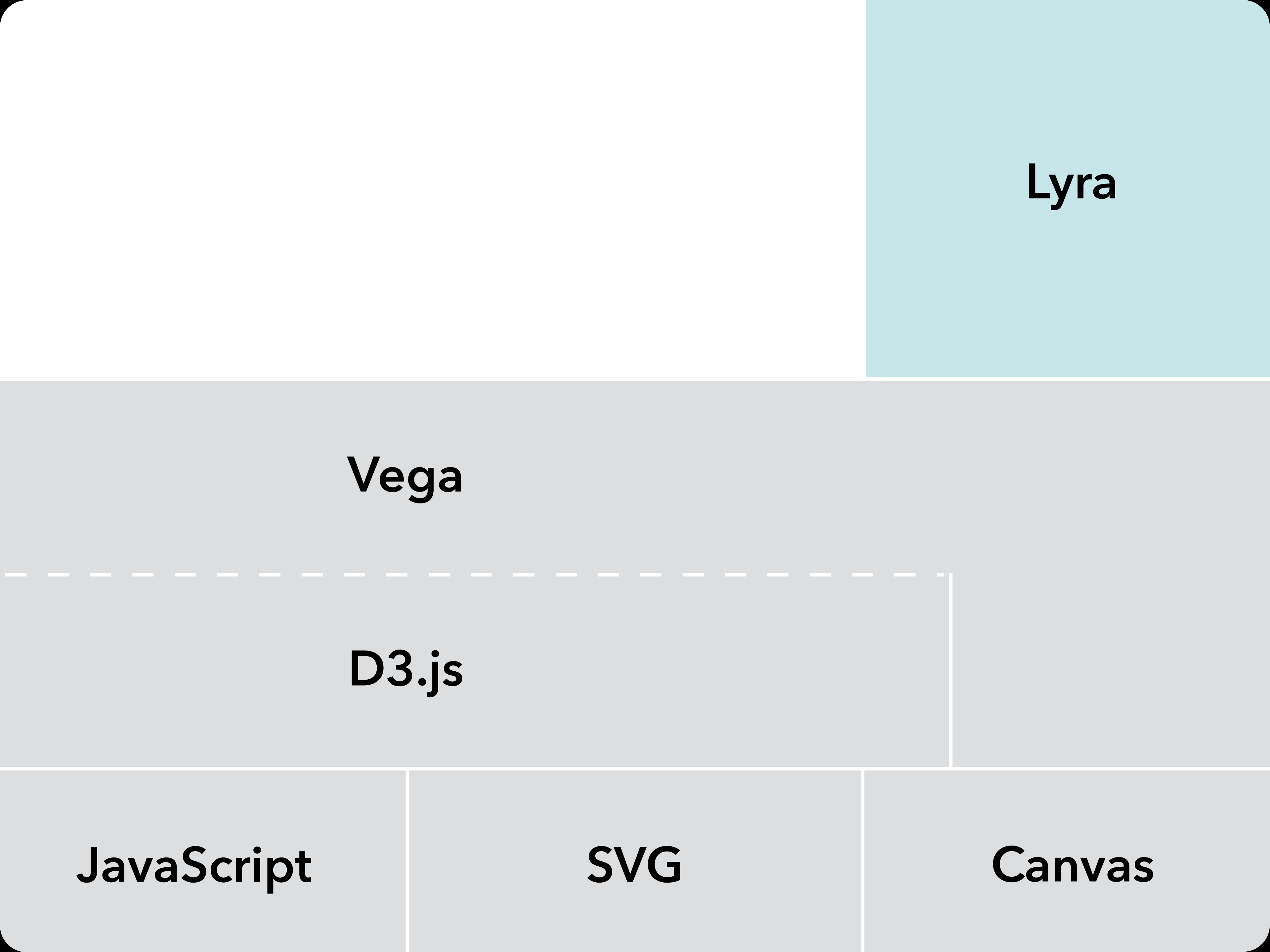
vega.min.js (188k)
Source (GitHub)

Vega is a visualization grammar, a declarative format for creating, saving and sharing visualization designs.

With Vega you can describe data visualizations in a JSON format, and generate interactive views using either HTML5 Canvas or SVG.

Read the tutorial, browse the documentation, join the discussion, and explore visualizations using the web-based Vega Editor.


Vega
D3.js
JavaScript
SVG
Canvas


Lyra
Vega
D3.js
JavaScript
SVG
Canvas

UW Interactive Data Lab PROJECTS

The Lyra Visualization Design Environment (VDE) alpha

Arvind Satyanarayan, Kanit "Ham" Wongsuphasawat, Jeffrey Heer

idl.cs.washington.edu/projects/lyra

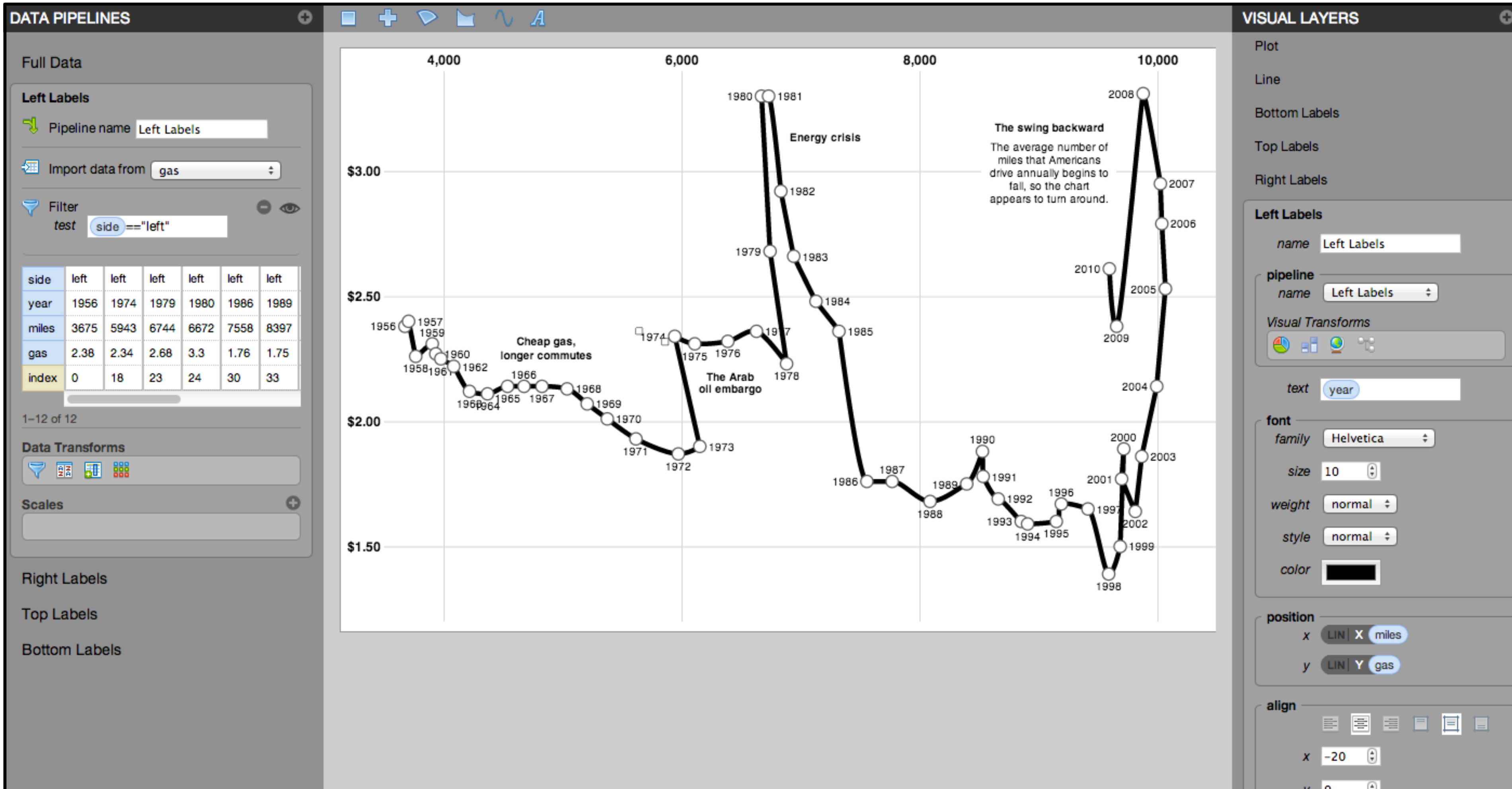
William Playfair's classic chart comparing the price of wheat and wages in England recreated in the Lyra VDE.

ABSTRACT

Lyra is an interactive environment that enables custom visualization design without writing any code. Graphical "marks" can be bound to data fields using property drop zones; dynamically positioned using connectors; and directly moved, rotated, and resized using handles. Lyra also provides a data pipeline interface for iterative visual specification of data transformations and layout algorithms. Lyra is more expressive than interactive systems like Tableau, allowing designers to create custom visualizations comparable to hand-coded visualizations built with D3 or Processing. These visualizations can then be easily published and reused on the Web.

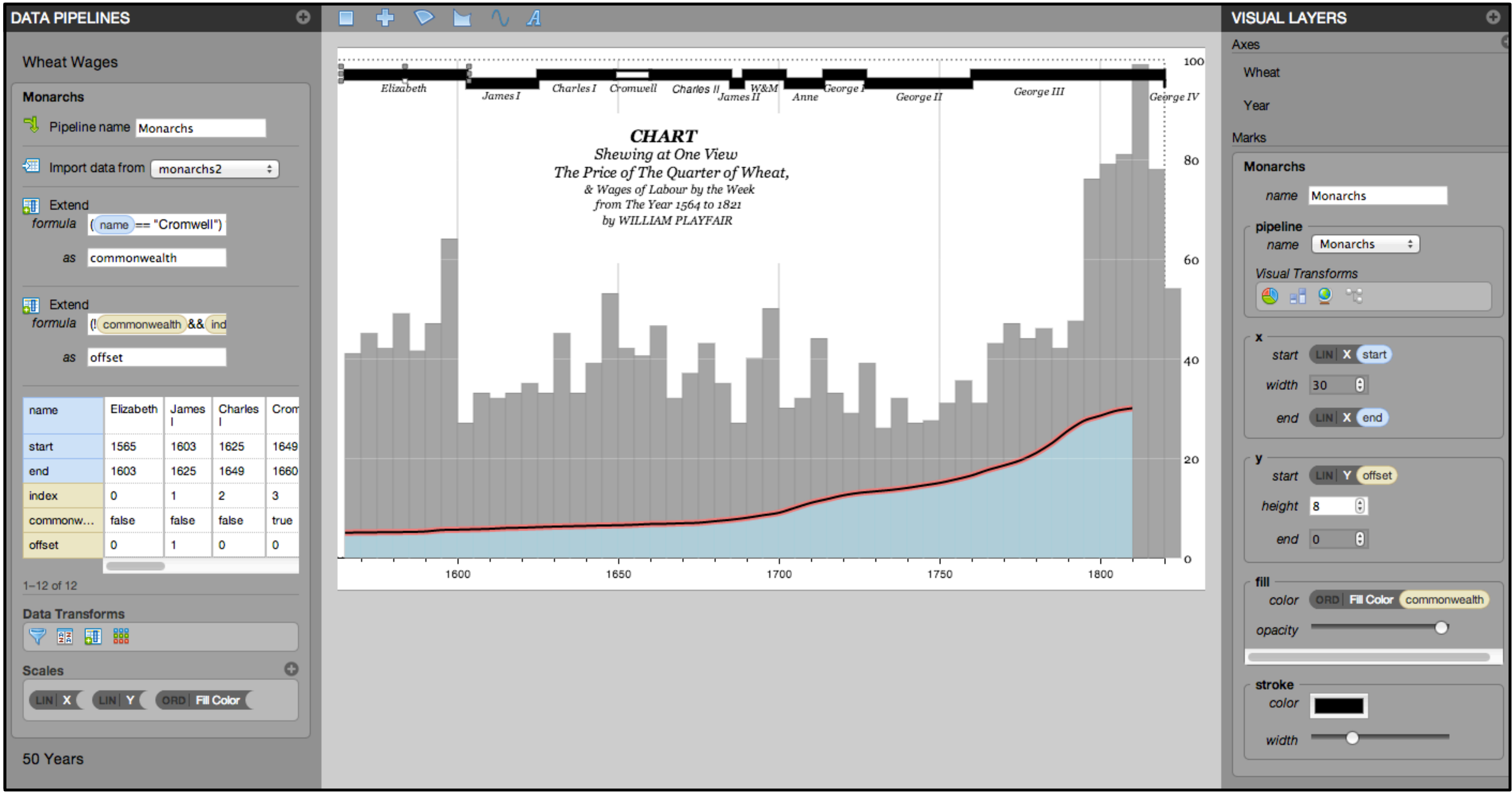
Lyra: An Interactive Visualization Design Environment

Lyra A Visualization Design Environment



Driving Shifts into Reverse by Hannah Fairfield, NYTimes

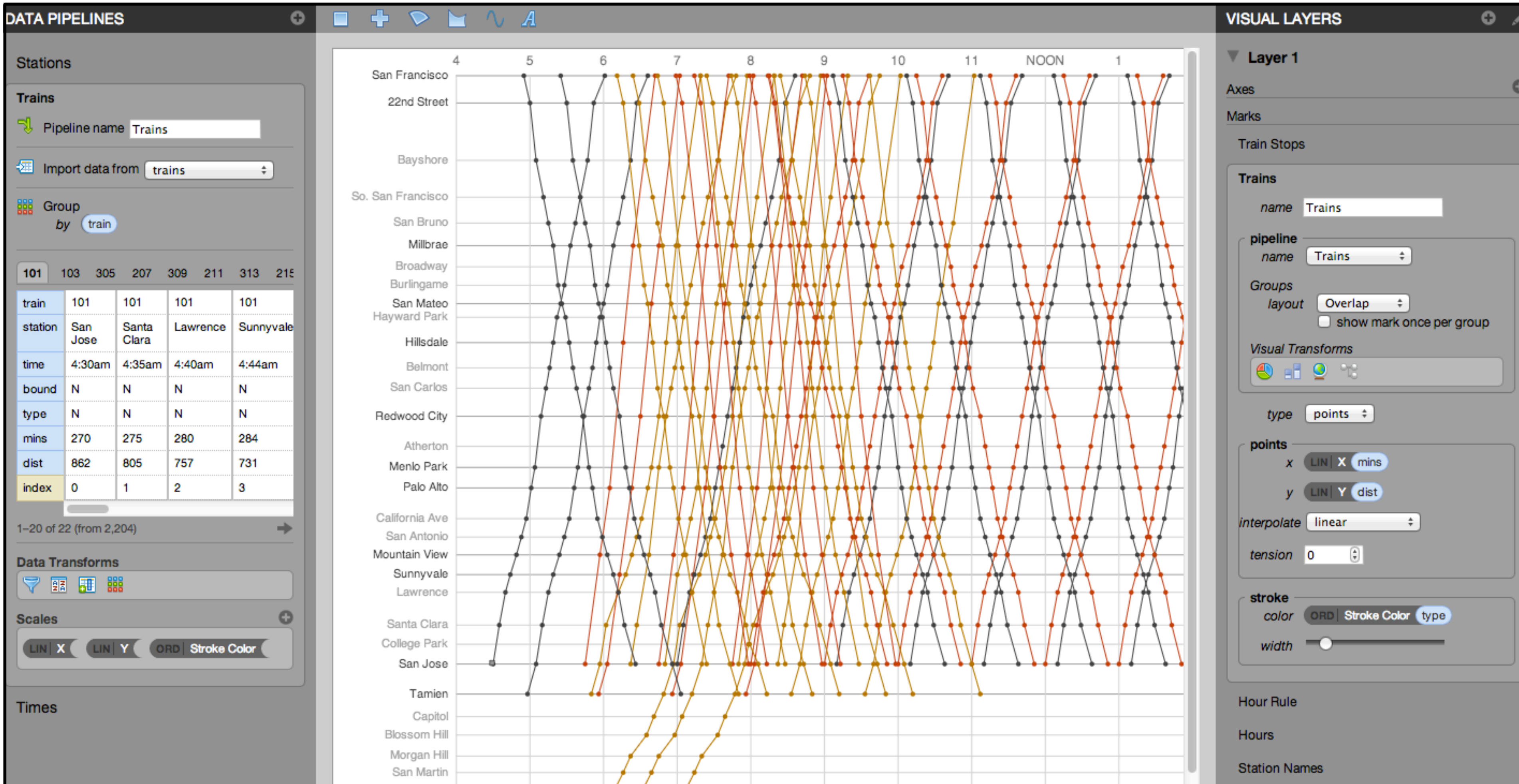
Lyra A Visualization Design Environment



name	Elizabeth	James I	Charles I	Crom
start	1565	1603	1625	1649
end	1603	1625	1649	1660
index	0	1	2	3
commonw...	false	false	false	true
offset	0	1	0	0

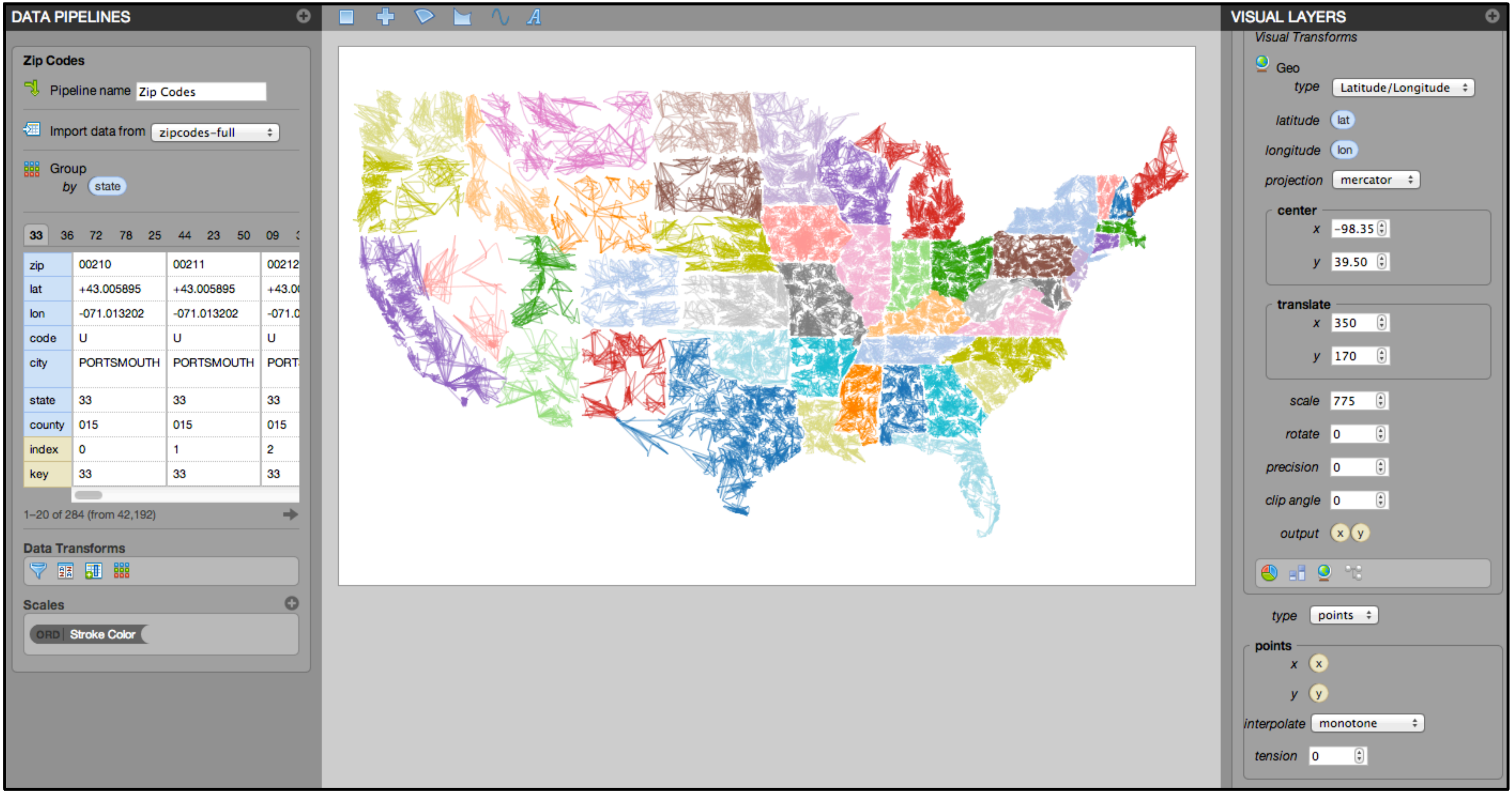
by William Playfair

Lyra A Visualization Design Environment



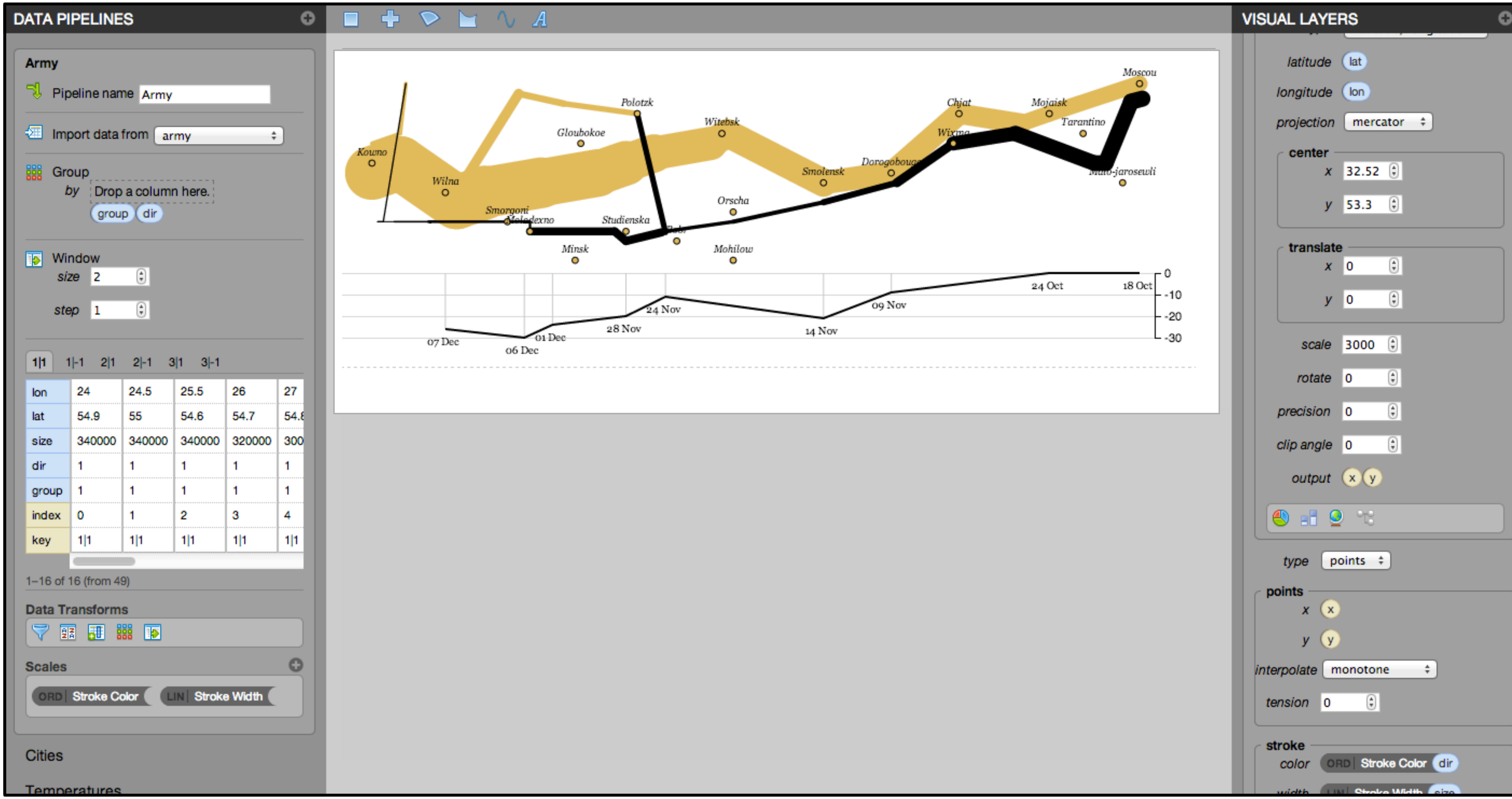
based on the **Railway Timetable** by E. J. Marey

Lyra A Visualization Design Environment

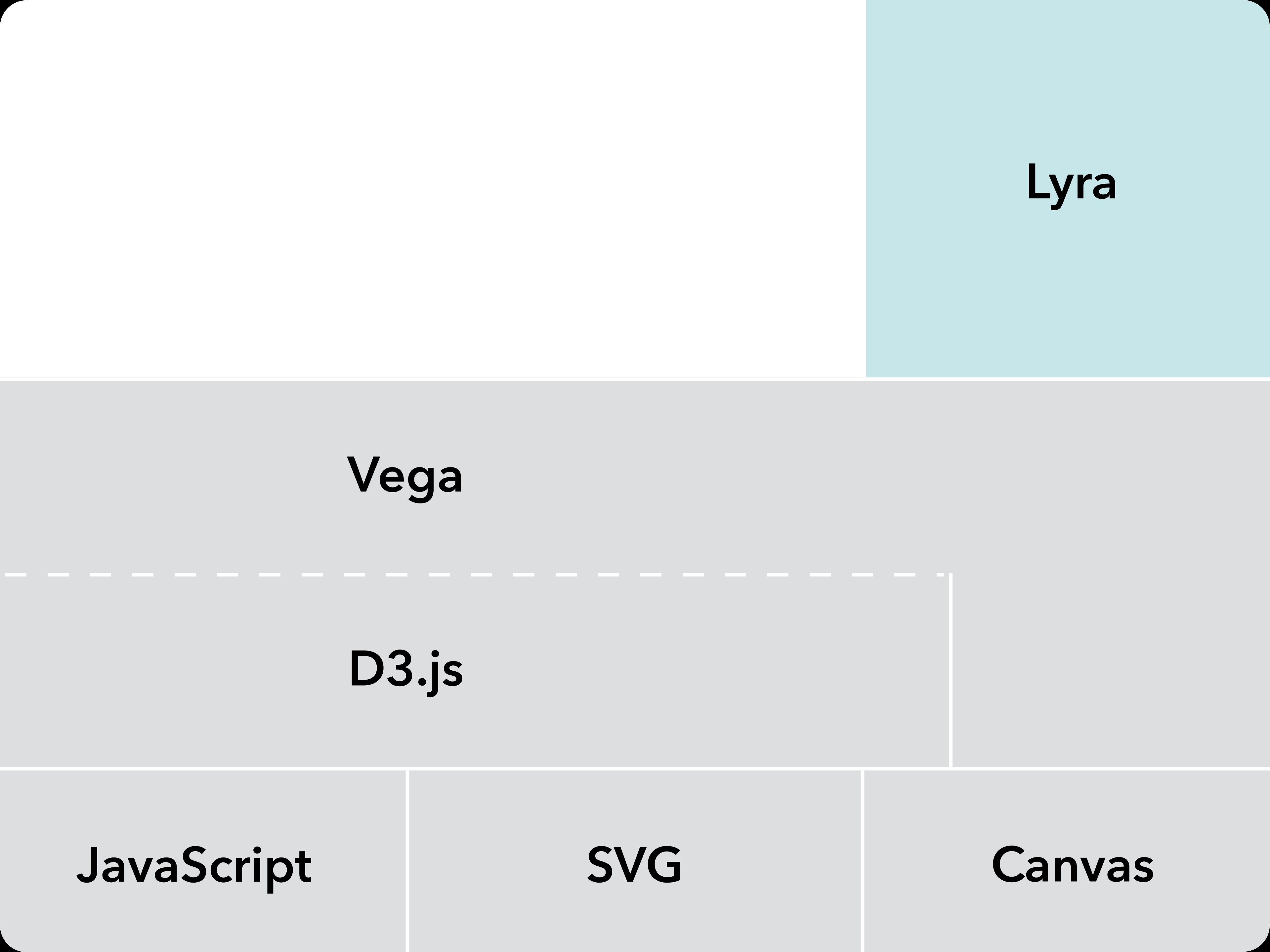


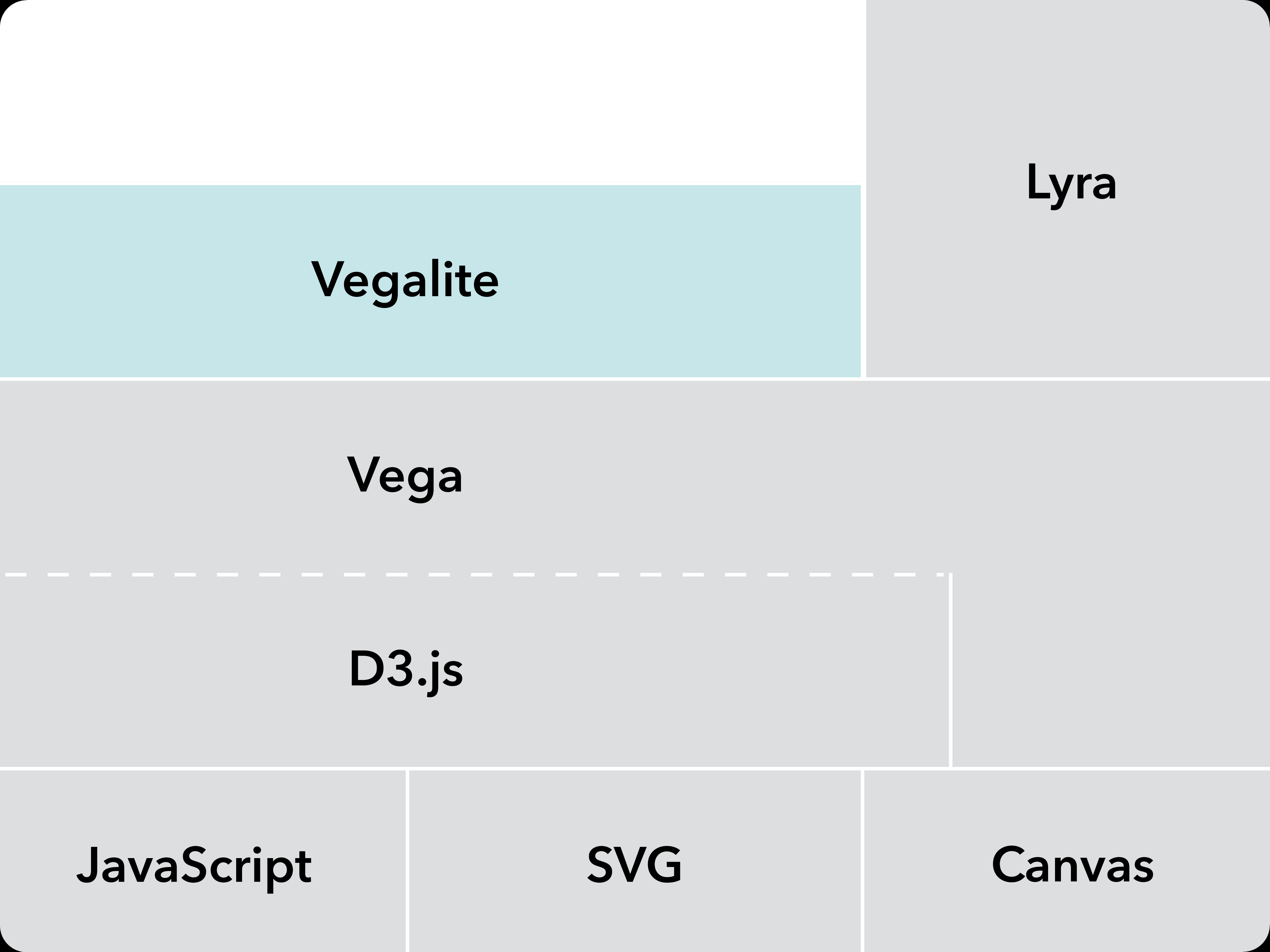
ZipScribble by Robert Kosara

Lyra A Visualization Design Environment



Napoleon's March by Charles Minard


Lyra
Vega
D3.js
JavaScript
SVG
Canvas


Lyra
Vegalite
Vega
D3.js
JavaScript
SVG
Canvas

Vegalite

A formal model for statistical graphics
Inspired by *Grammar of Graphics* & *Tableau*

Includes **data transformation** & **encoding**

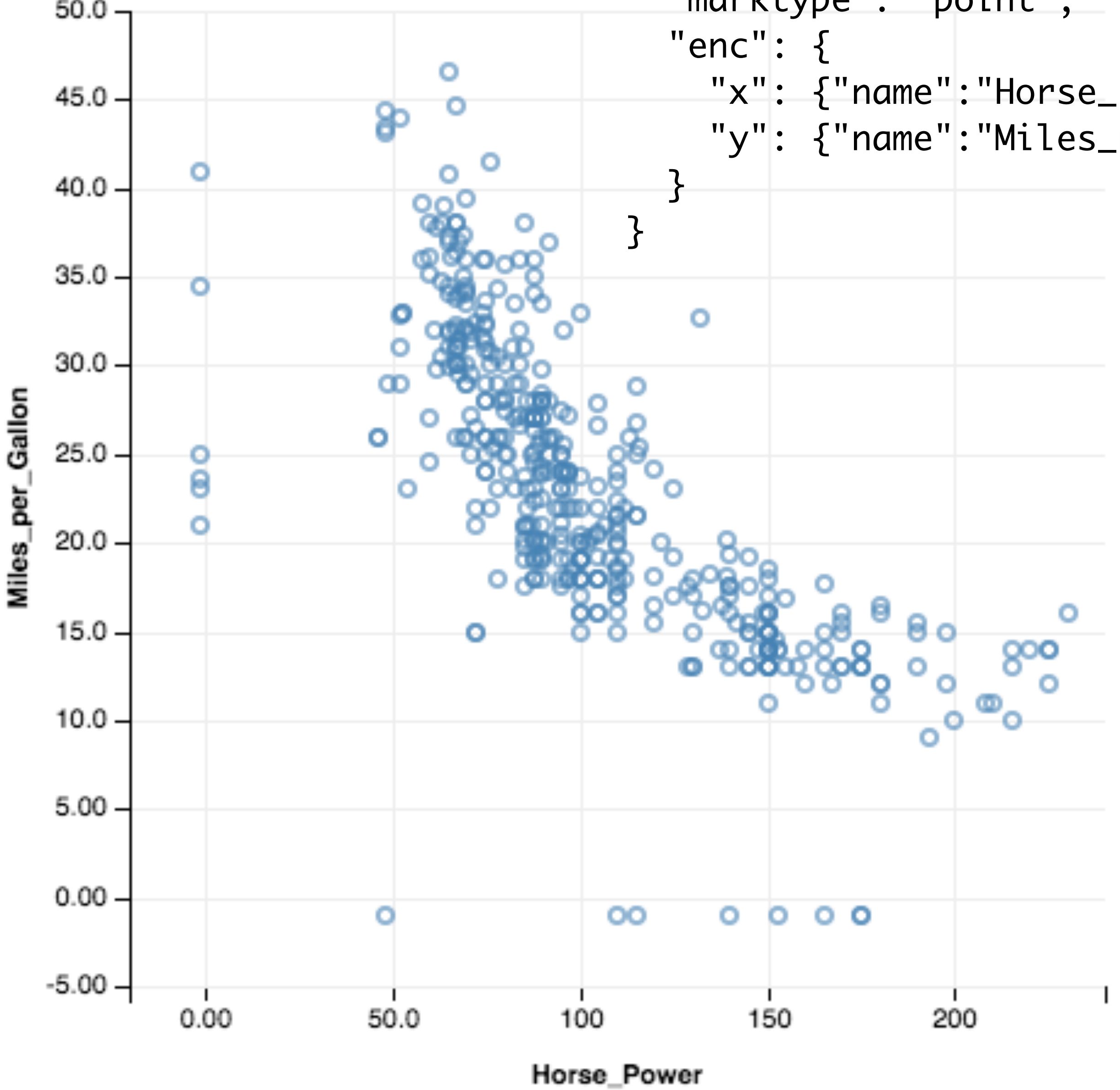
Vegalite

A formal model for statistical graphics
Inspired by *Grammar of Graphics* & *Tableau*

Includes **data transformation** & **encoding**

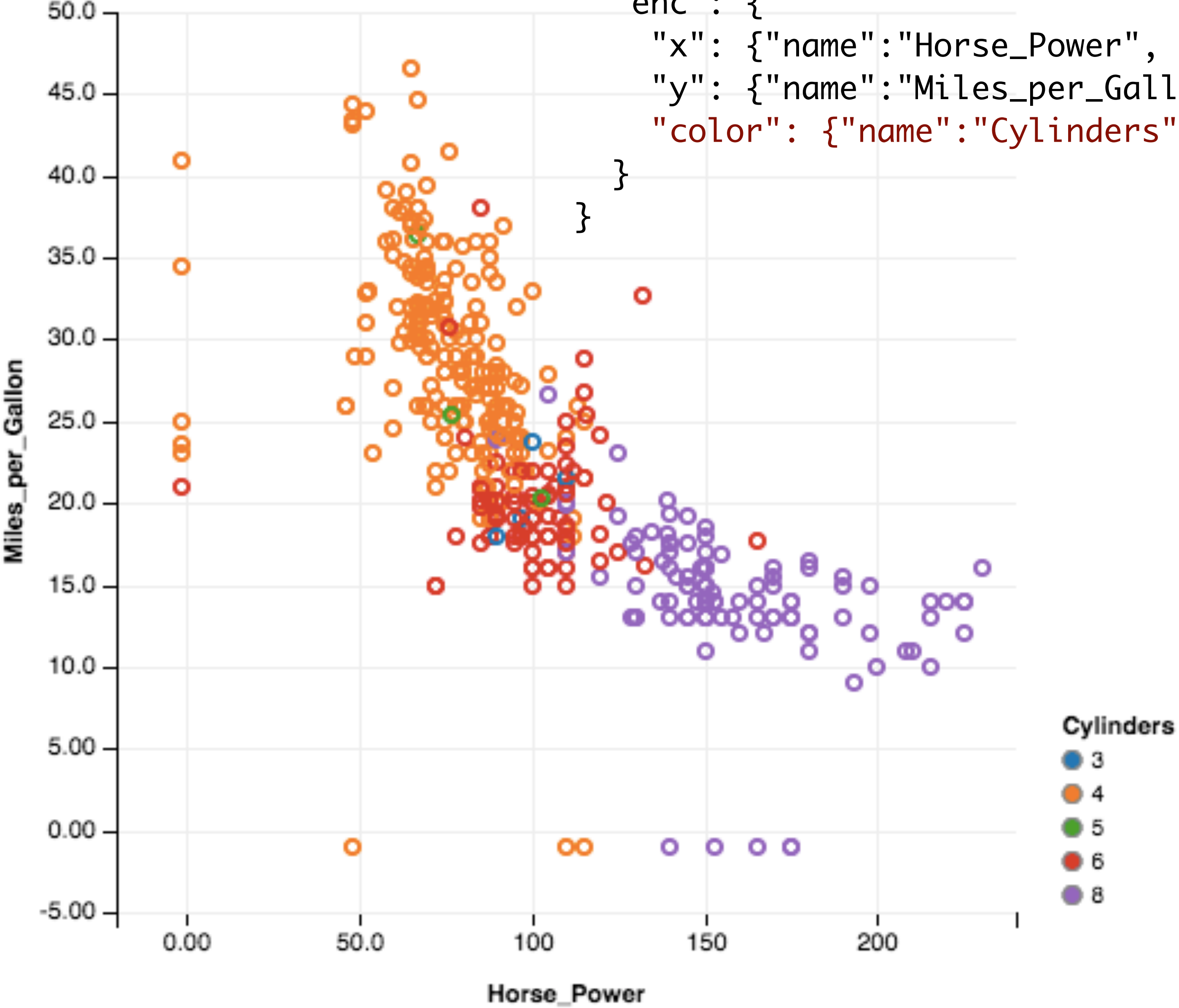
Uses a simple, concise **JSON format** that compiles to full-blown **Vega specifications**

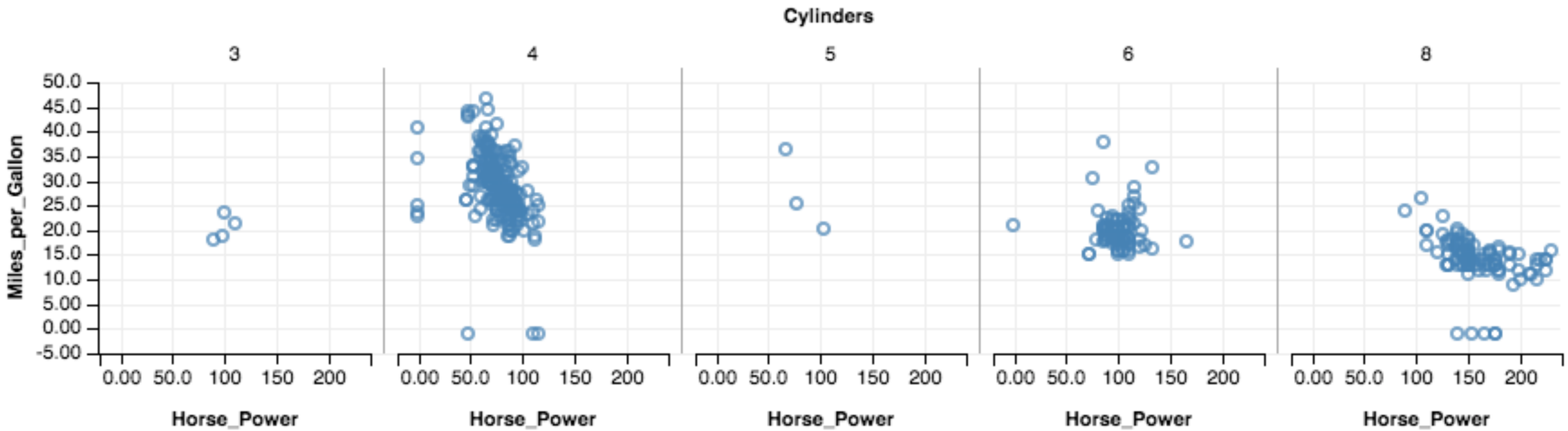
Easy **programmatic generation**




```
{
  "marktype": "point",
  "enc": {
    "x": {"name":"Horse_Power", "type":"Q"},
    "y": {"name":"Miles_per_Gallon", "type":"Q"}
  }
}
```

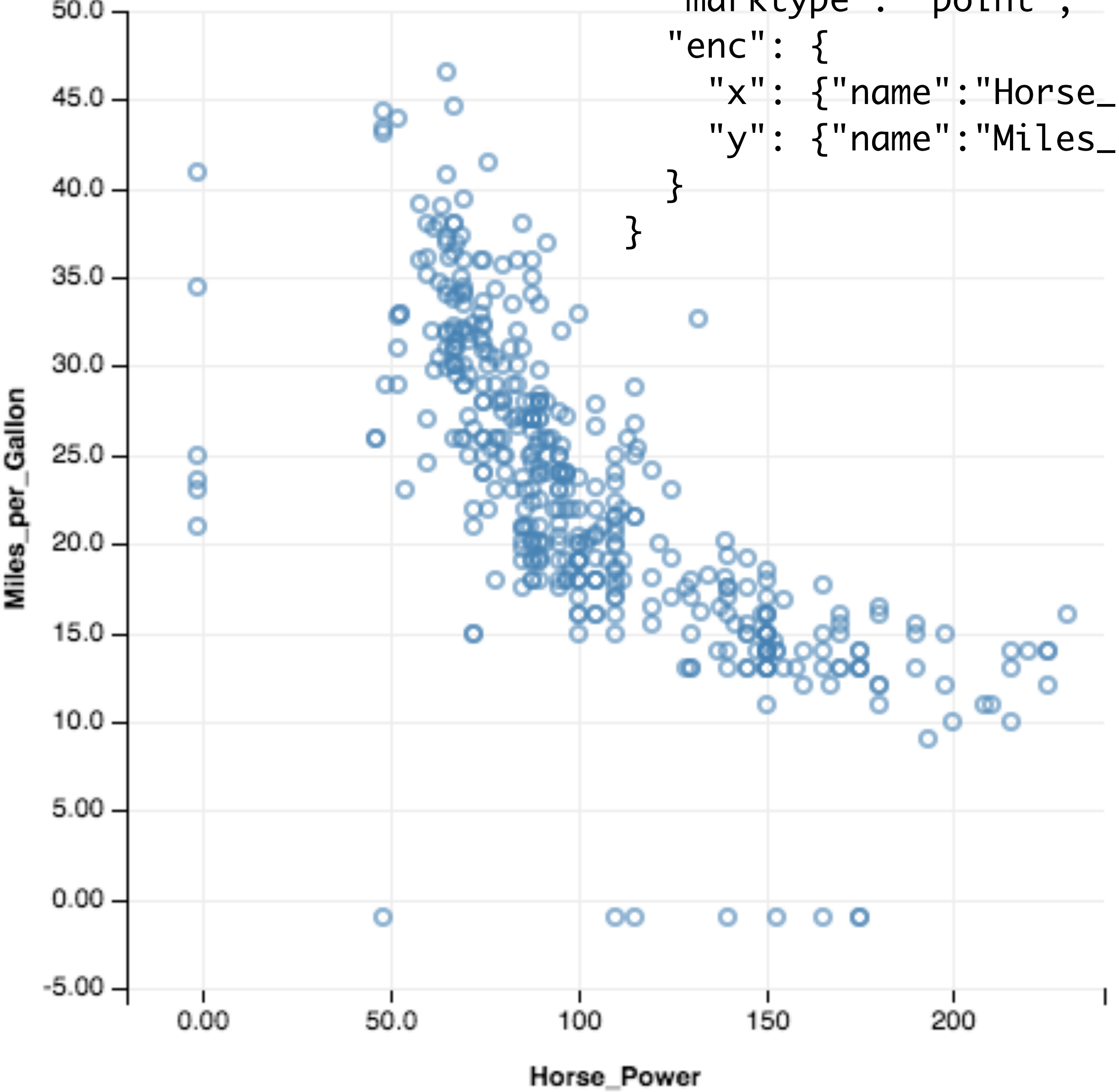
```
{
  "marktype": "point",
  "enc": {
    "x": {"name":"Horse_Power", "type":"Q"},
    "y": {"name":"Miles_per_Gallon", "type":"Q"},
    "color": {"name":"Cylinders", "type":"O"}
  }
}
```

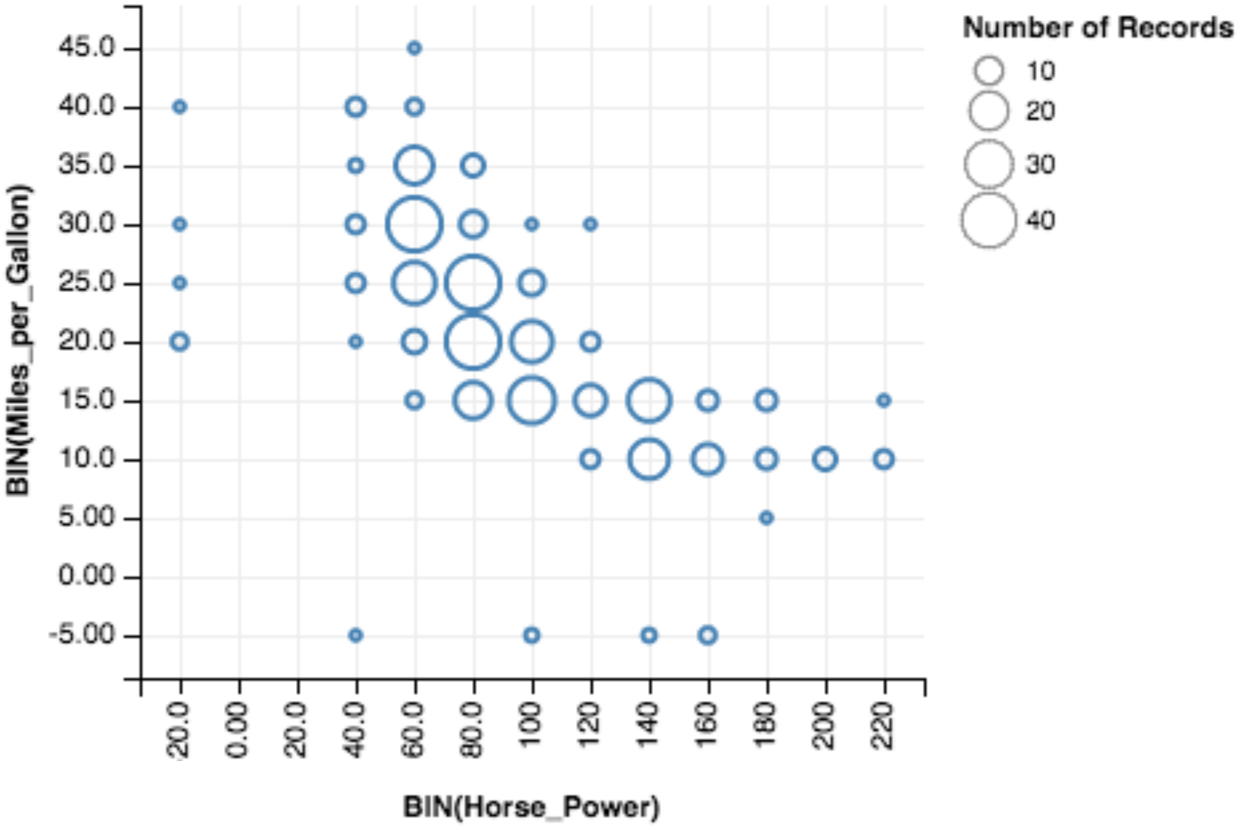





```
{
  "marktype": "point",
  "enc": {
    "x": {"name":"Horse_Power", "type":"Q"},
    "y": {"name":"Miles_per_Gallon", "type":"Q"},
    "col": {"name":"Cylinders", "type":"O"}
  }
}
```

```
{
  "marktype": "point",
  "enc": {
    "x": {"name":"Horse_Power", "type":"Q"},
    "y": {"name":"Miles_per_Gallon", "type":"Q"}
  }
}
```






```
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    "y": {"name":"Miles_per_Gallon", "type":"Q", "bin":{"maxbins":15}},
    "size": {"name":"*", "type":"Q", "aggr":"count"}
  }
}
```
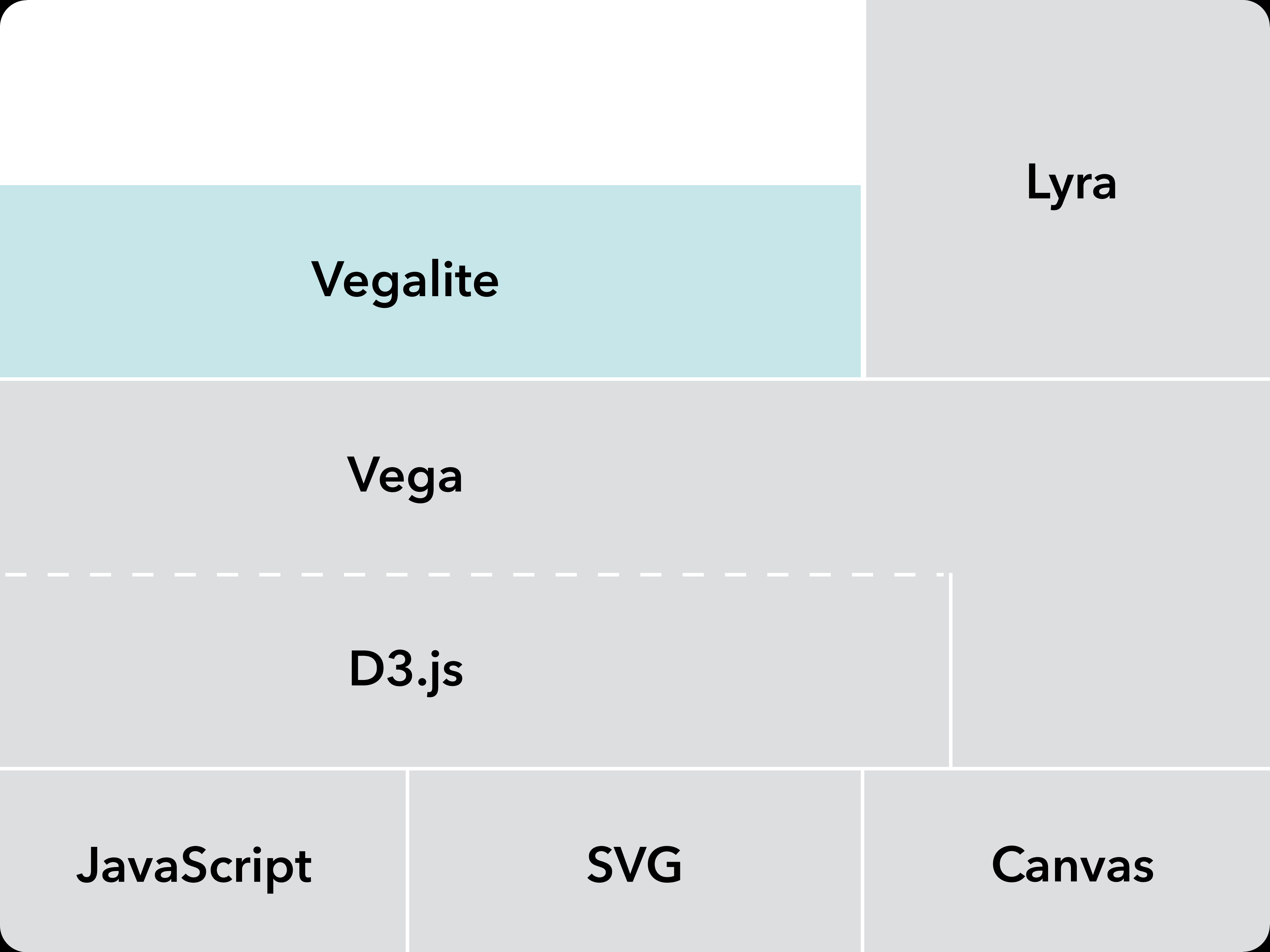
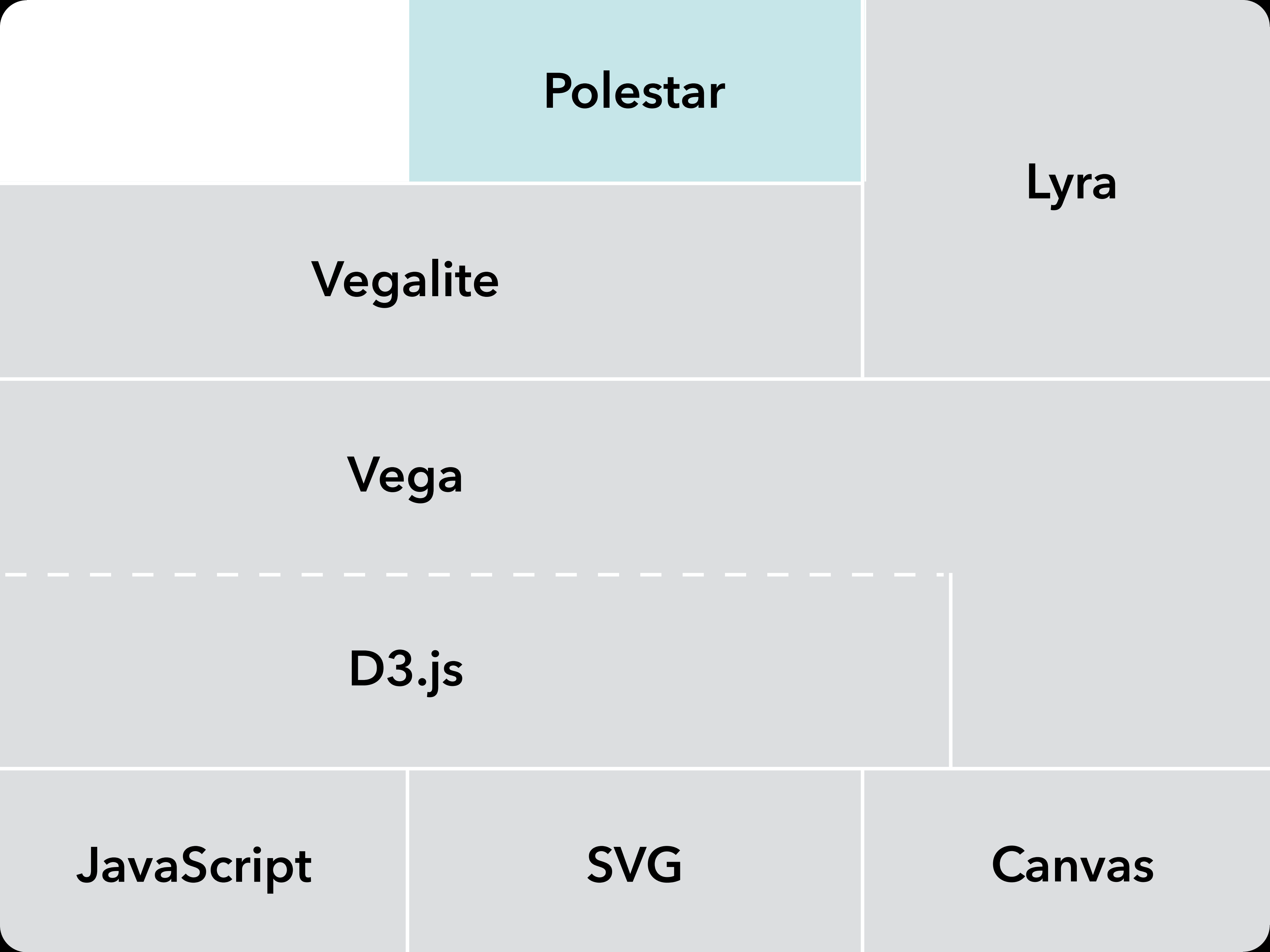


Lyra
Vegalite
Vega
D3.js
JavaScript
SVG
Canvas

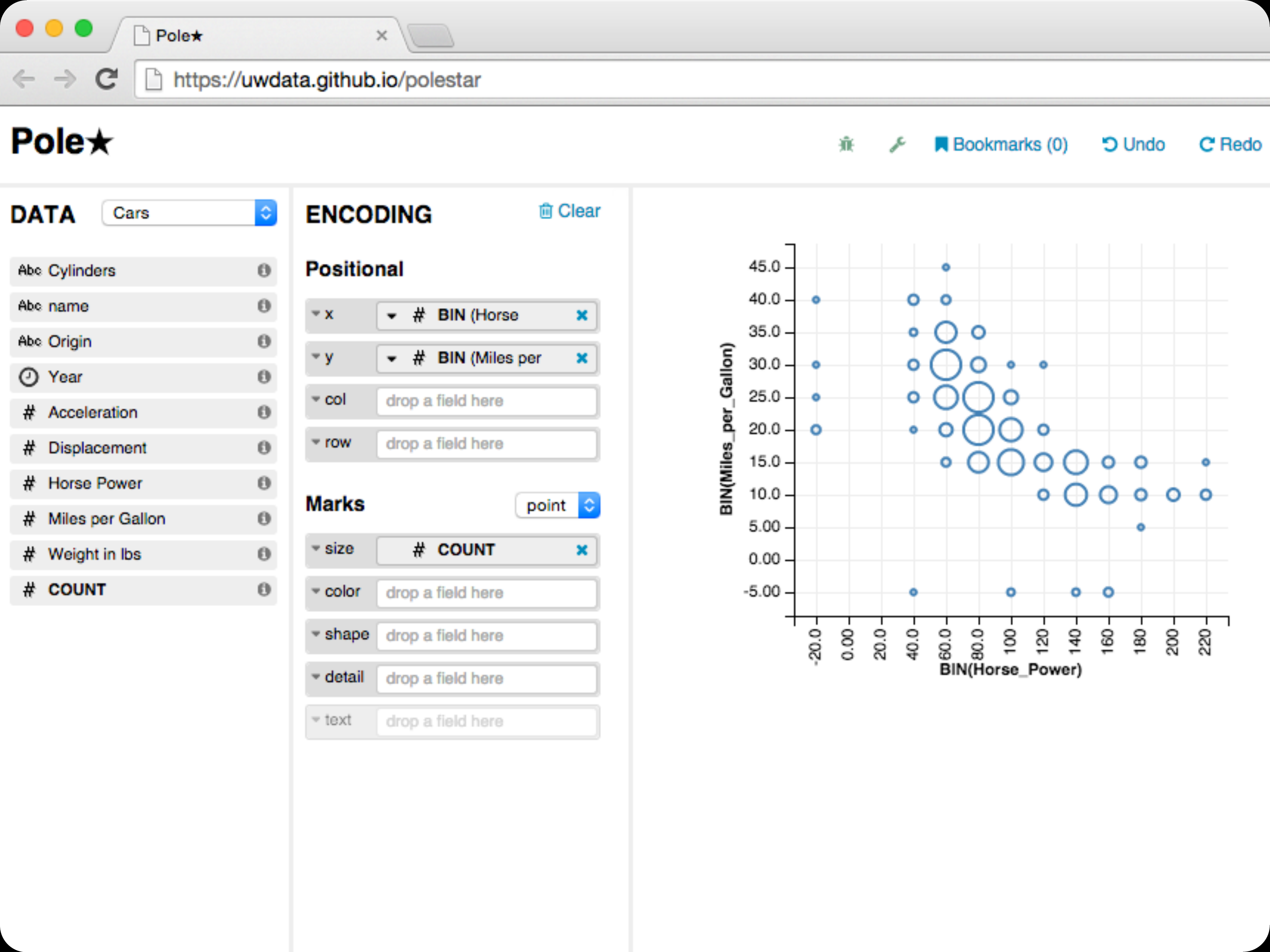

Polestar
Lyra
Vegalite
Vega
D3.js
JavaScript
SVG
Canvas

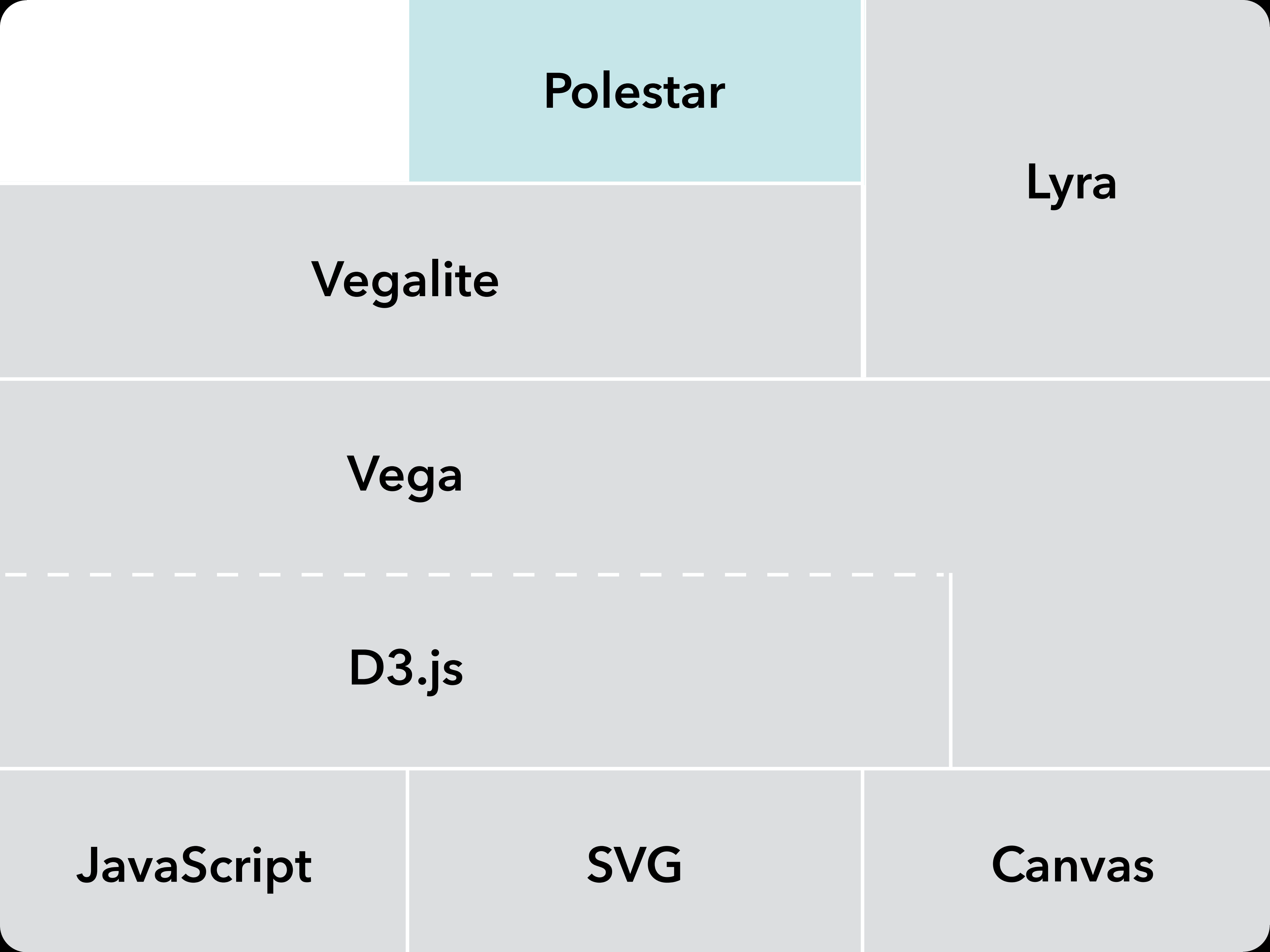
Polestar

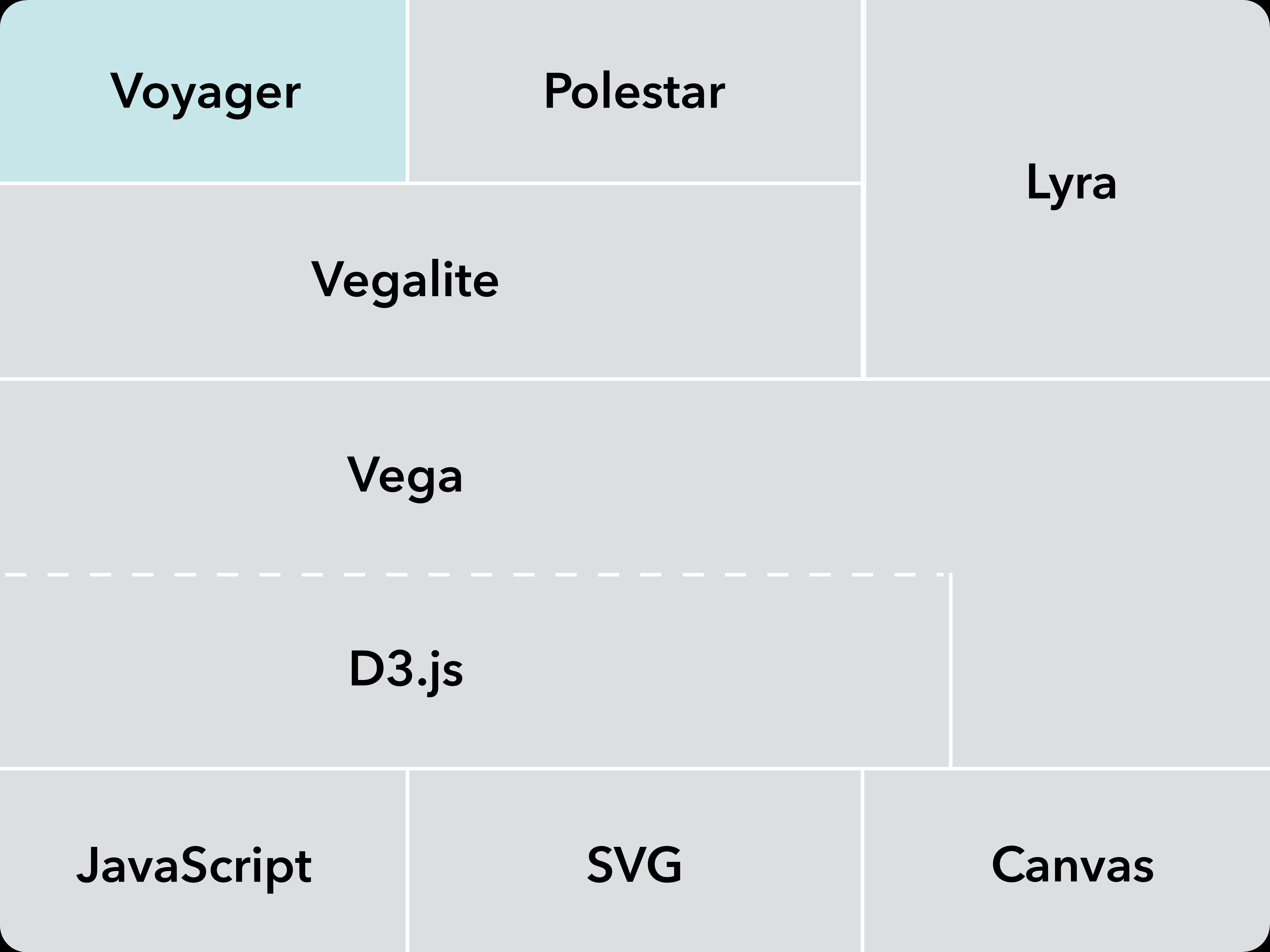
A graphical interface for **Vegalite**

Rapid visualization via drag-and-drop

Named in honor of **Polaris**, the research project that led to **Tableau**.


Pole★
https://uwdata.github.io/polestar
Pole★
Bookmarks (0)
Undo
Redo
DATA
Cars
Abc Cylinders
Abc name
Abc Origin
Year
Acceleration
Displacement
Horse Power
Miles per Gallon
Weight in lbs
COUNT
ENCODING
Clear
Positional
x
BIN (Horse
y
BIN (Miles per
col
drop a field here
row
drop a field here
Marks
point
size
COUNT
color
drop a field here
shape
drop a field here
detail
drop a field here
text
drop a field here
BIN(Miles_per_Gallon)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.00
0.00
-5.00
-20.0
0.00
20.0
40.0
60.0
80.0
100
120
140
160
180
200
220
BIN(Horse_Power)


Polestar
Lyra
Vegalite
Vega
D3.js
JavaScript
SVG
Canvas


Voyager
Polestar
Lyra
Vegalite
Vega
D3.js
JavaScript
SVG
Canvas

Voyager

Reduce tedious manual specification

Voyager

Reduce tedious manual specification

Support early-stage data exploration

Encourage *data coverage*

Discourage *premature fixation*

Voyager

Reduce tedious manual specification

Support early-stage data exploration
Encourage *data coverage*
Discourage *premature fixation*

Approach: browse a gallery of visualizations

Voyager

Reduce tedious manual specification

Support early-stage data exploration
Encourage *data coverage*
Discourage *premature fixation*

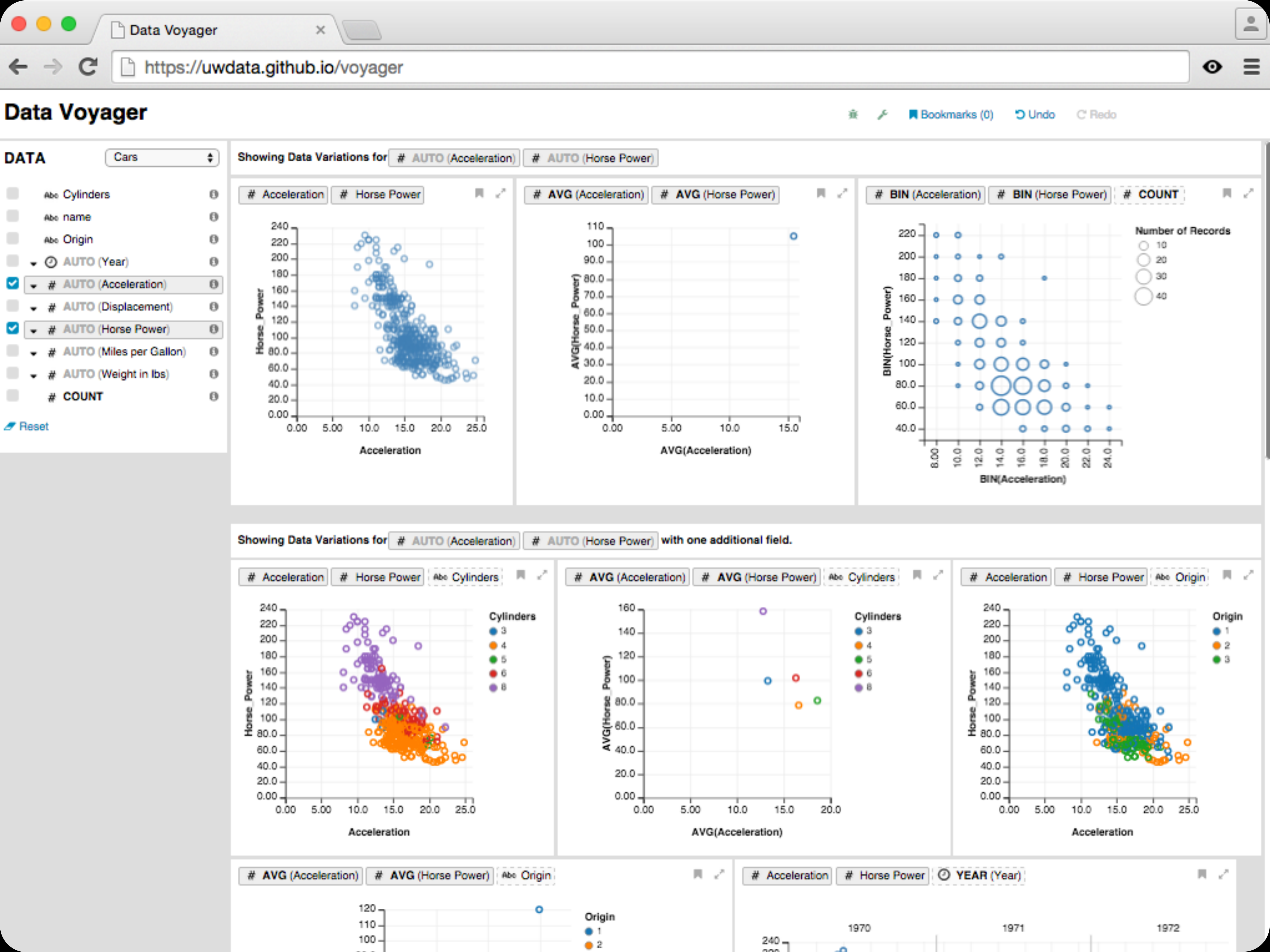
Approach: browse a gallery of visualizations
Challenge - *combinatorial explosion!*

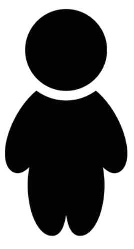
Voyager

Reduce tedious manual specification

Support early-stage data exploration
Encourage *data coverage*
Discourage *premature fixation*

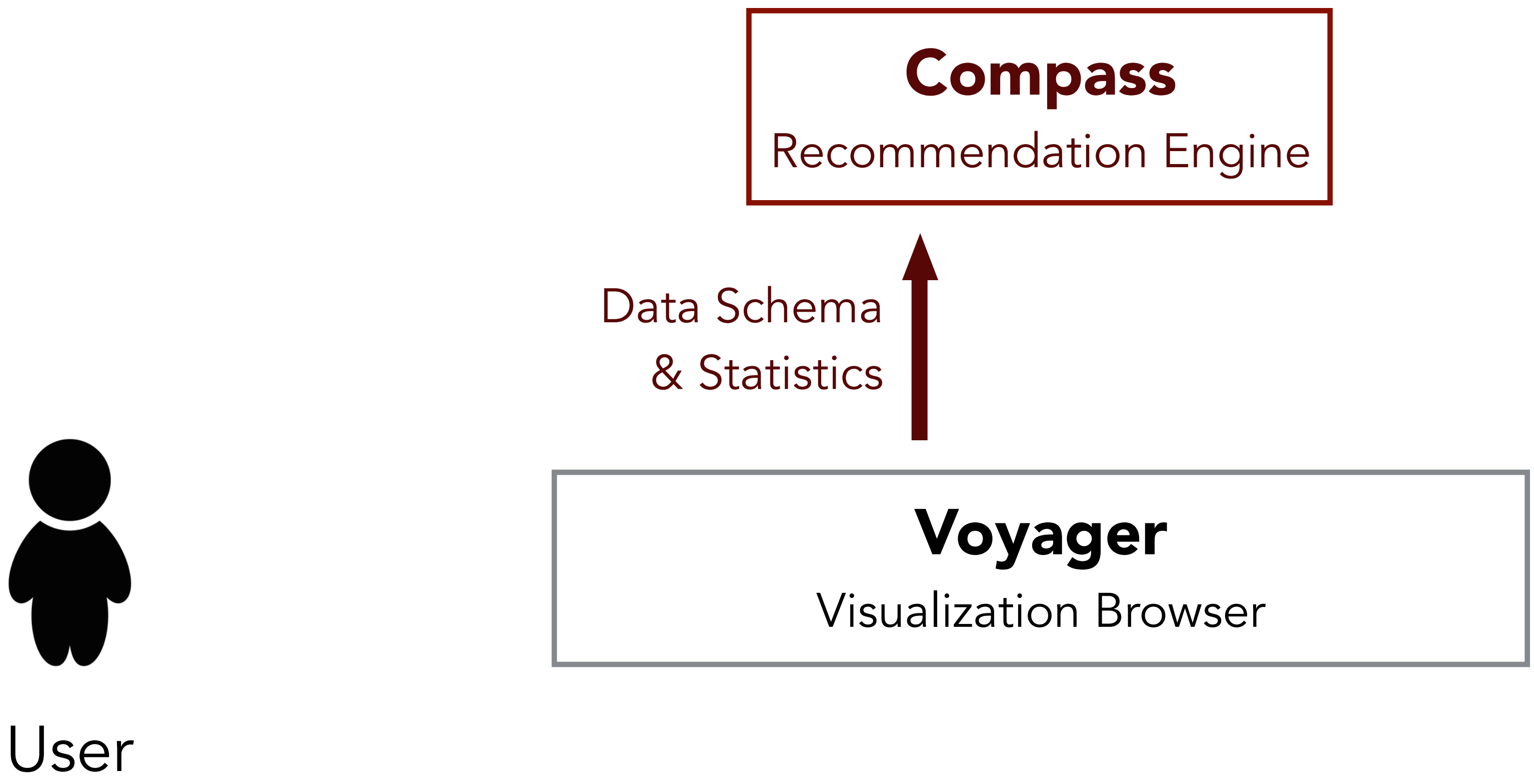
Approach: browse a gallery of visualizations
Challenge - *combinatorial explosion!*
Automatic recommendation of useful views
+ **end-user steering** to focus exploration

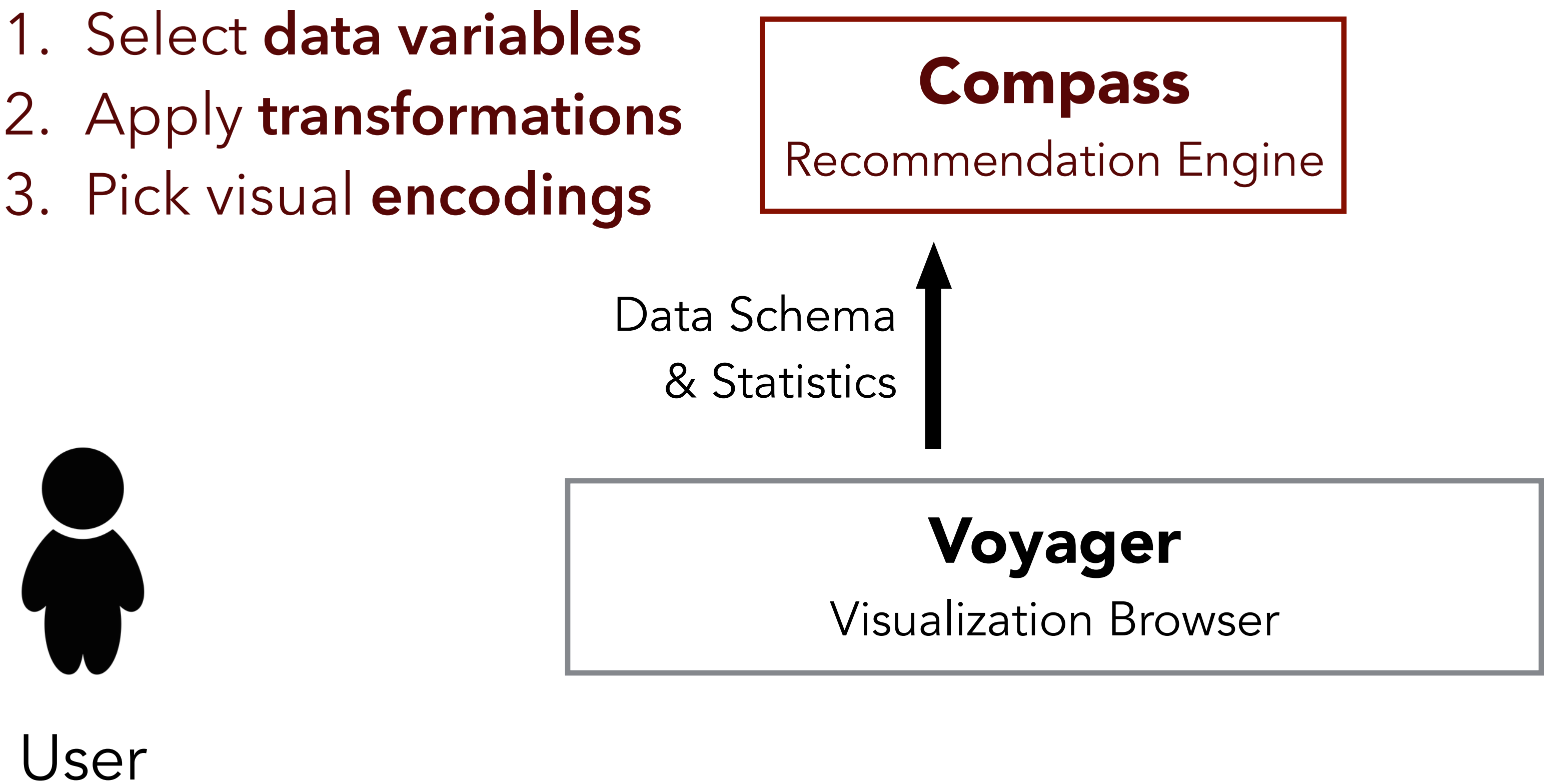

Data Voyager
https://uwdata.github.io/voyager
Data Voyager
Bookmarks (0)
Undo
Redo
DATA
Cars
Cylinders
name
Origin
AUTO (Year)
AUTO (Acceleration)
AUTO (Displacement)
AUTO (Horse Power)
AUTO (Miles per Gallon)
AUTO (Weight in lbs)
COUNT
Reset
Showing Data Variations for AUTO (Acceleration) AUTO (Horse Power)
Acceleration
Horse Power
Horse_Power
AVG (Acceleration)
AVG (Horse Power)
AVG(Horse_Power)
AVG(Acceleration)
BIN (Acceleration)
BIN (Horse Power)
COUNT
BIN(Horse_Power)
BIN(Acceleration)
Number of Records
Showing Data Variations for AUTO (Acceleration) AUTO (Horse Power) with one additional field.
Cylinders
Origin
YEAR (Year)
1970
1971
1972



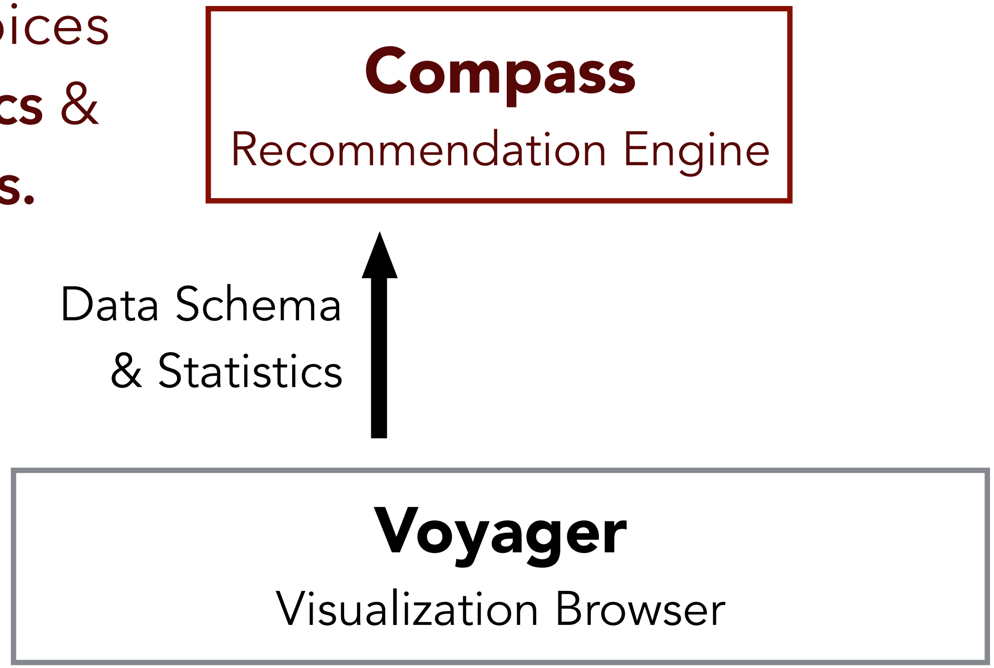
User

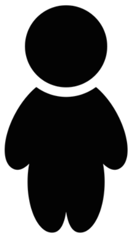

Data Set
Voyager
Visualization Browser
User


Compass
Recommendation Engine
Data Schema
& Statistics
Voyager
Visualization Browser
User

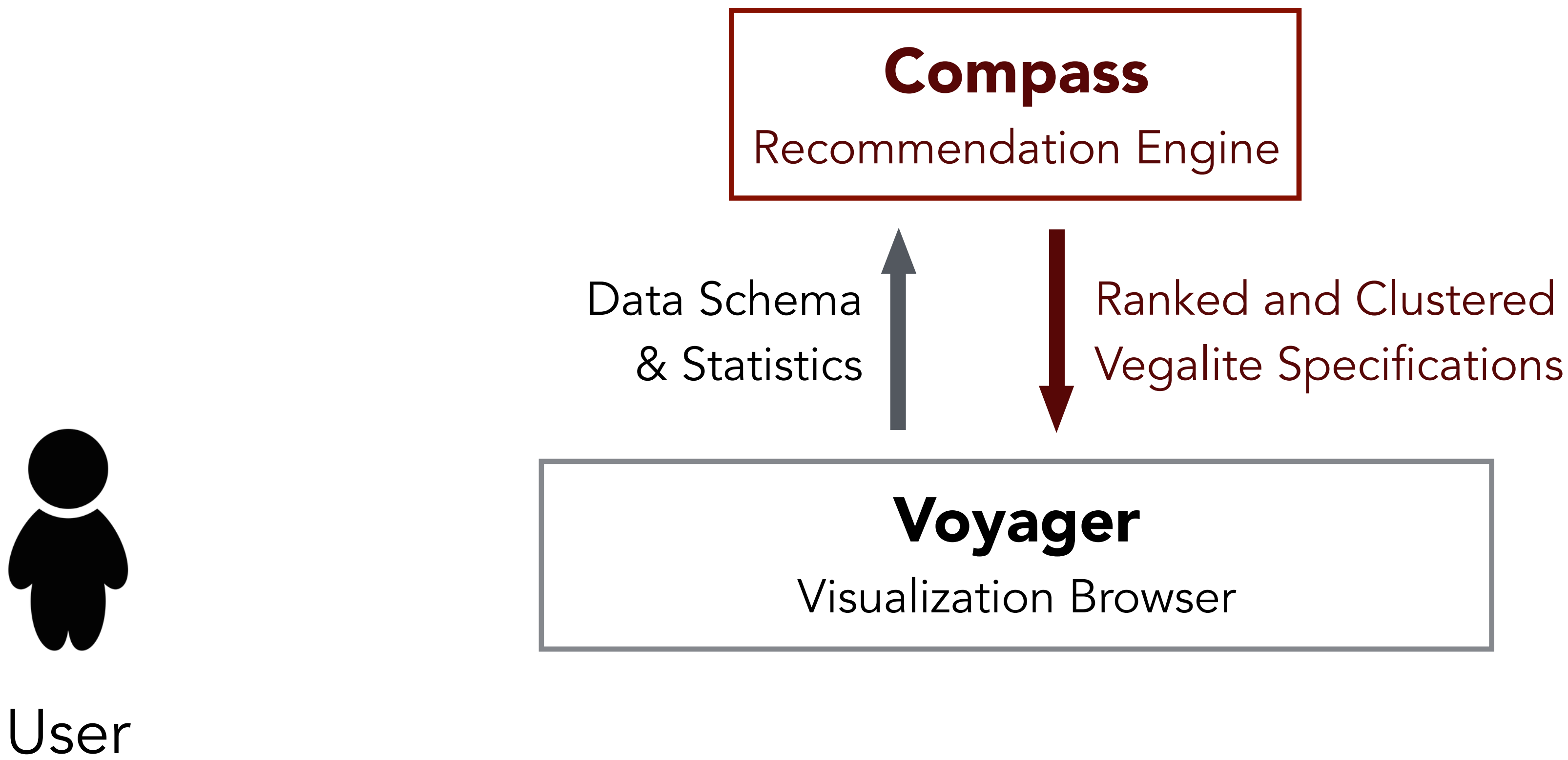

1. Select **data variables**
2. Apply **transformations**
3. Pick visual **encodings**
Compass
Recommendation Engine
Data Schema
& Statistics
Voyager
Visualization Browser
User

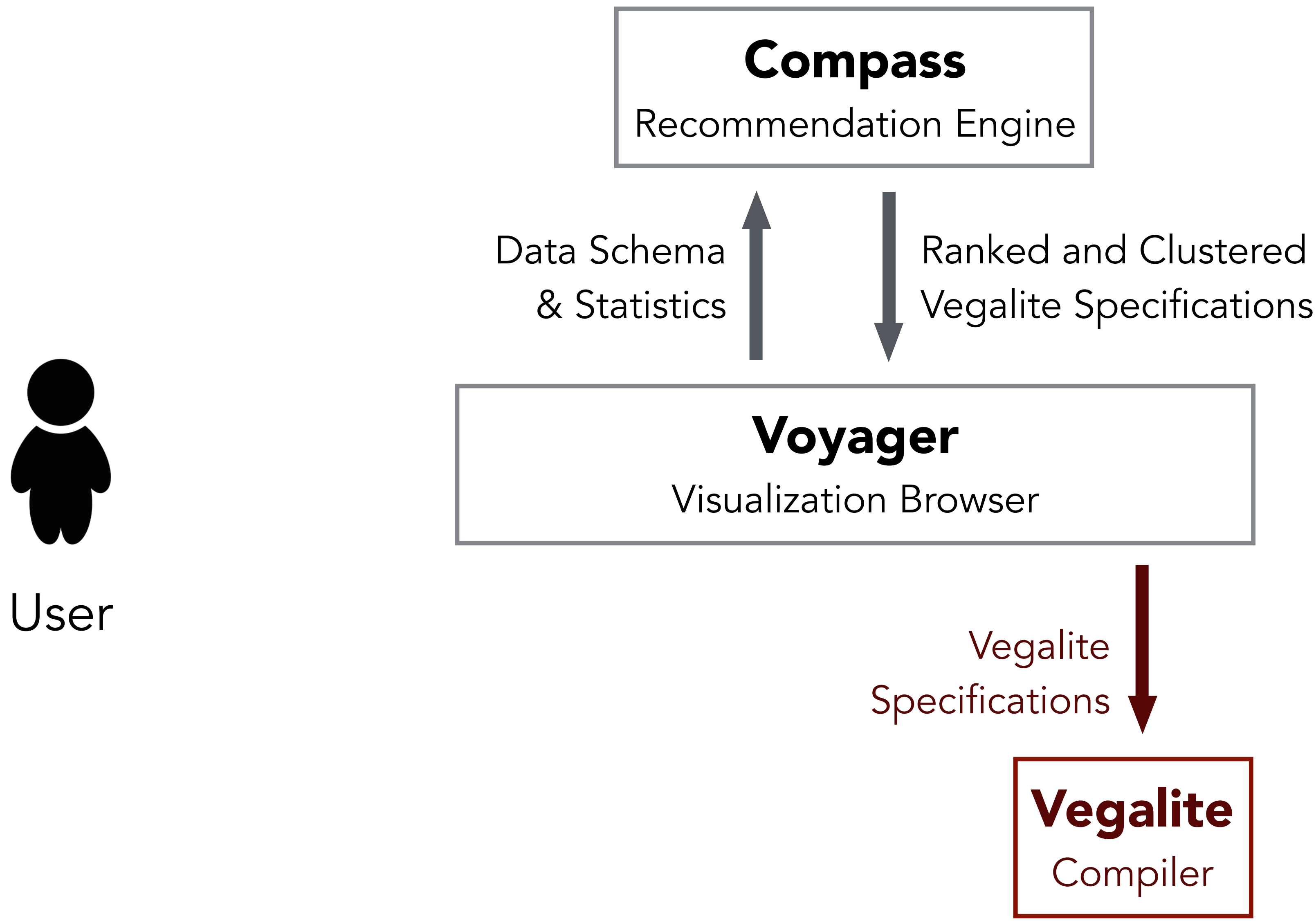
Constrain & rank choices by **data type**, **statistics** & **perceptual principles.**



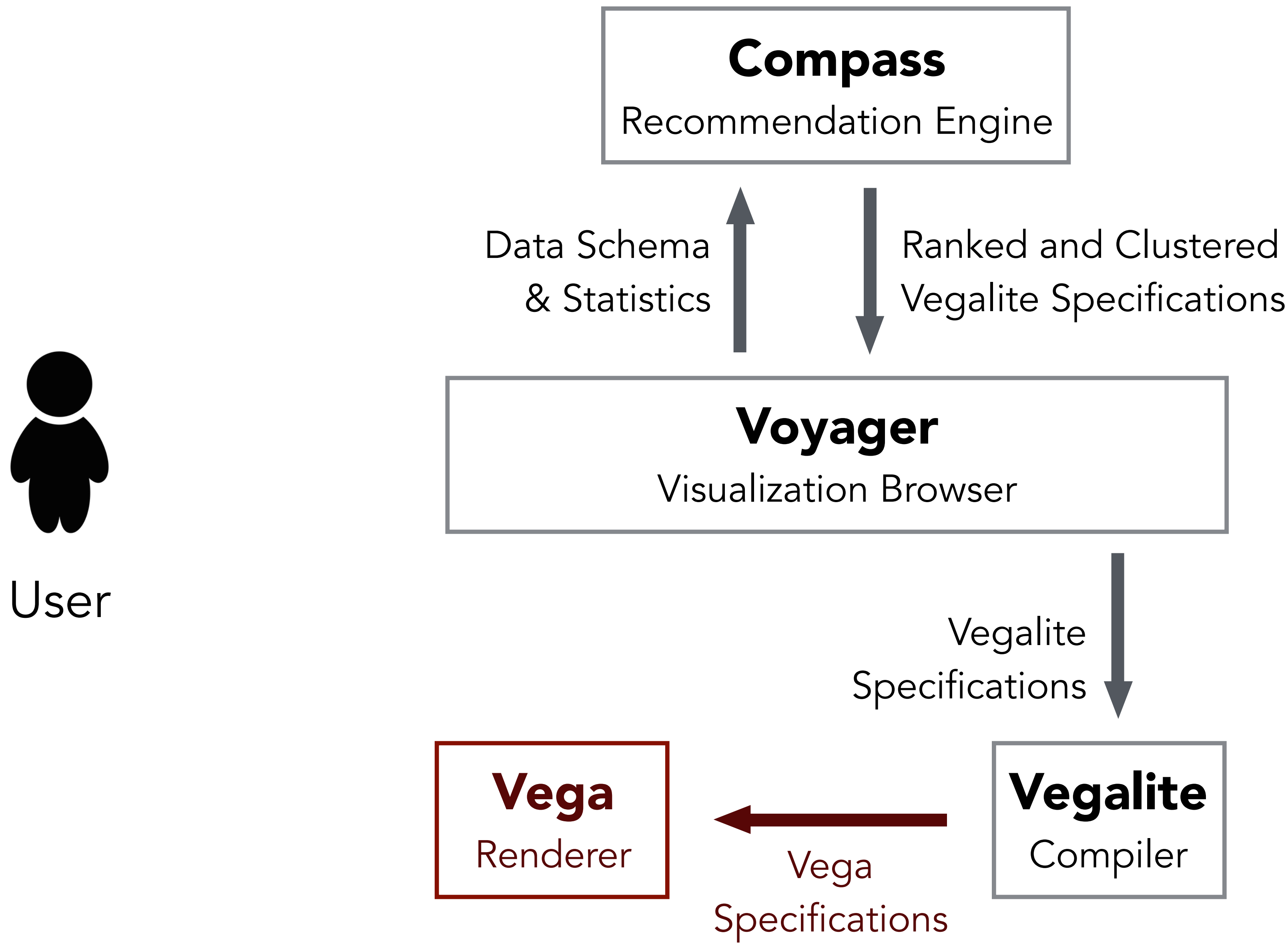


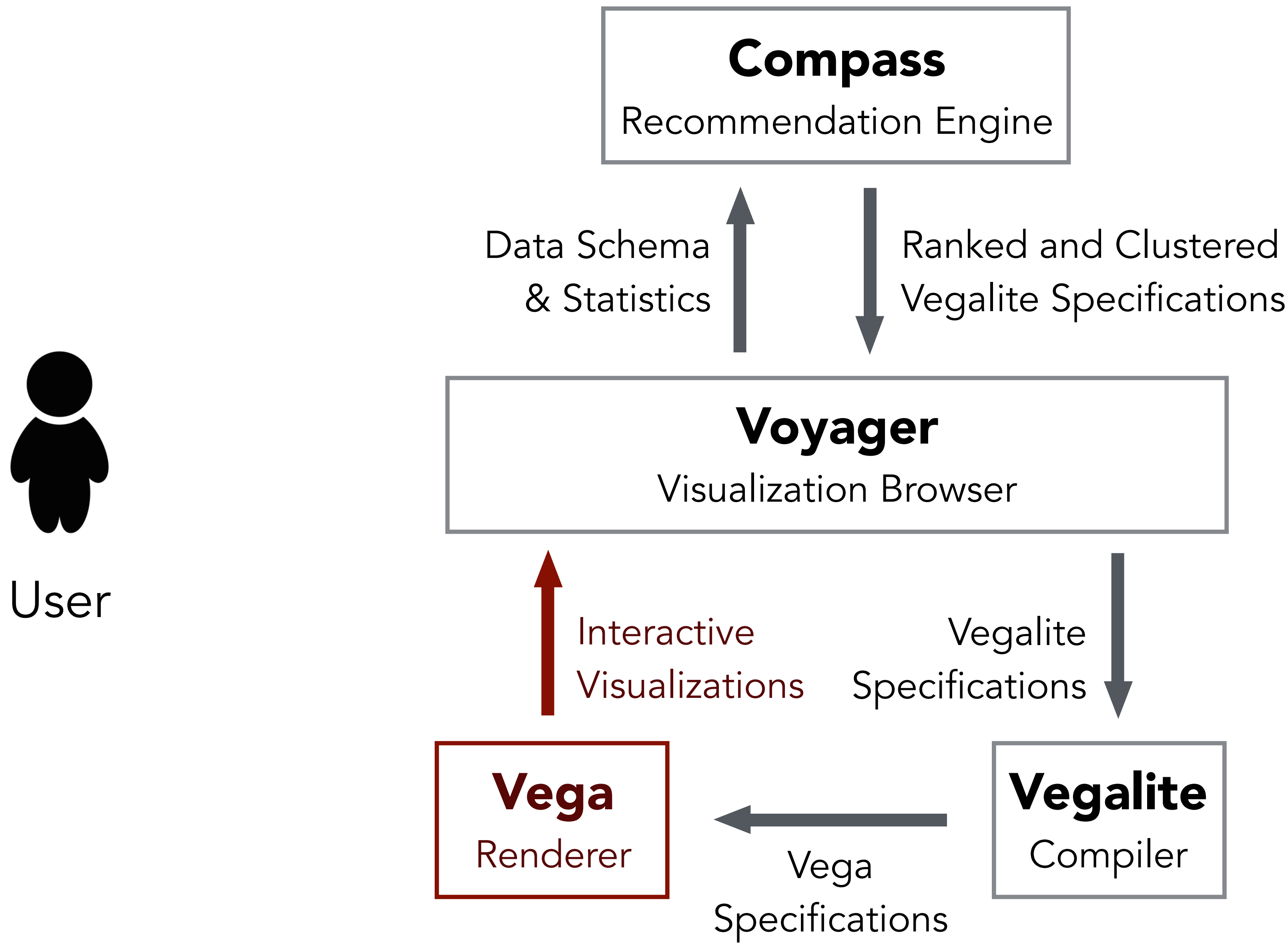
User


Compass
Recommendation Engine
Data Schema
& Statistics
Ranked and Clustered
Vegalite Specifications
Voyager
Visualization Browser
User

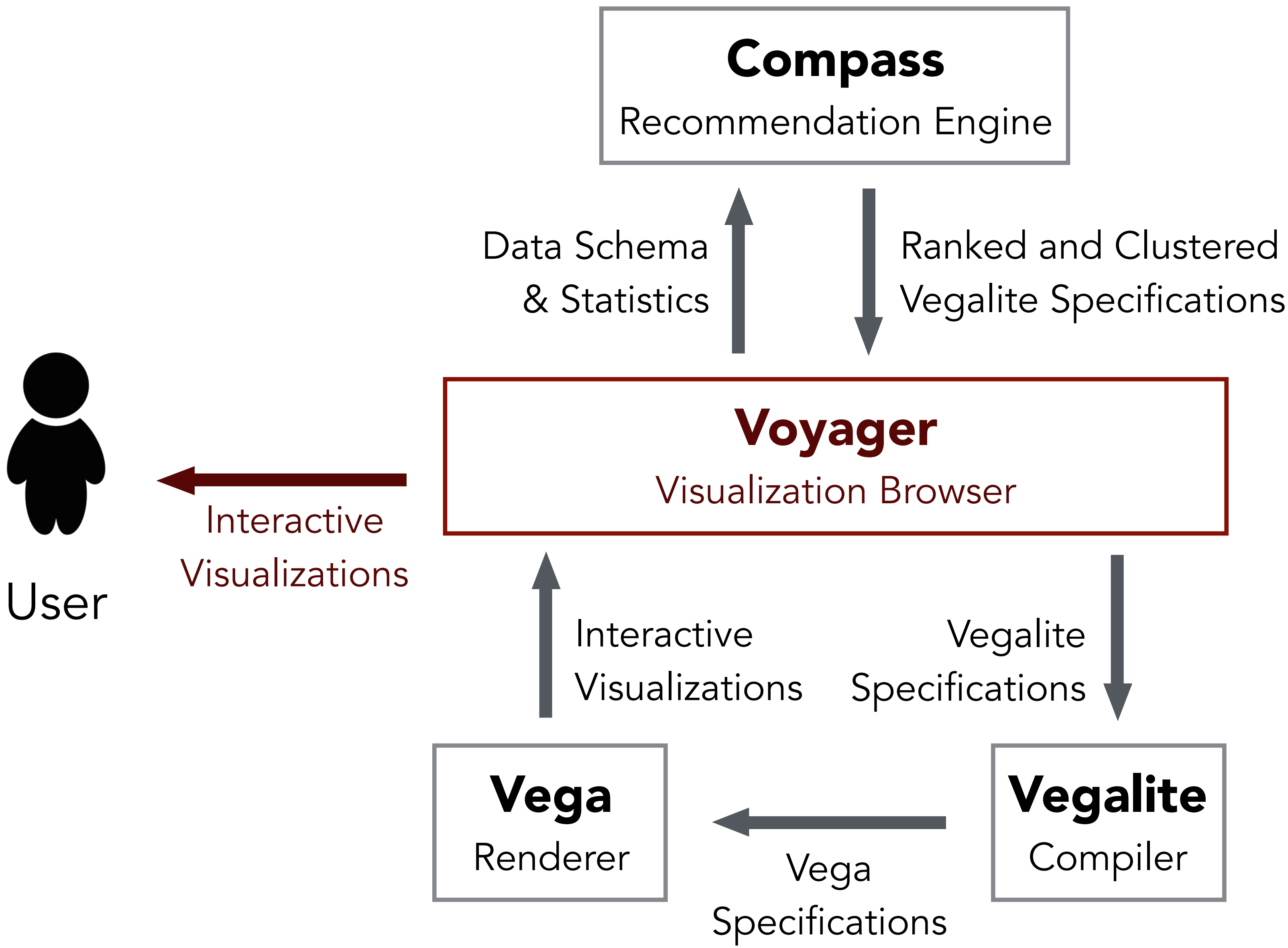


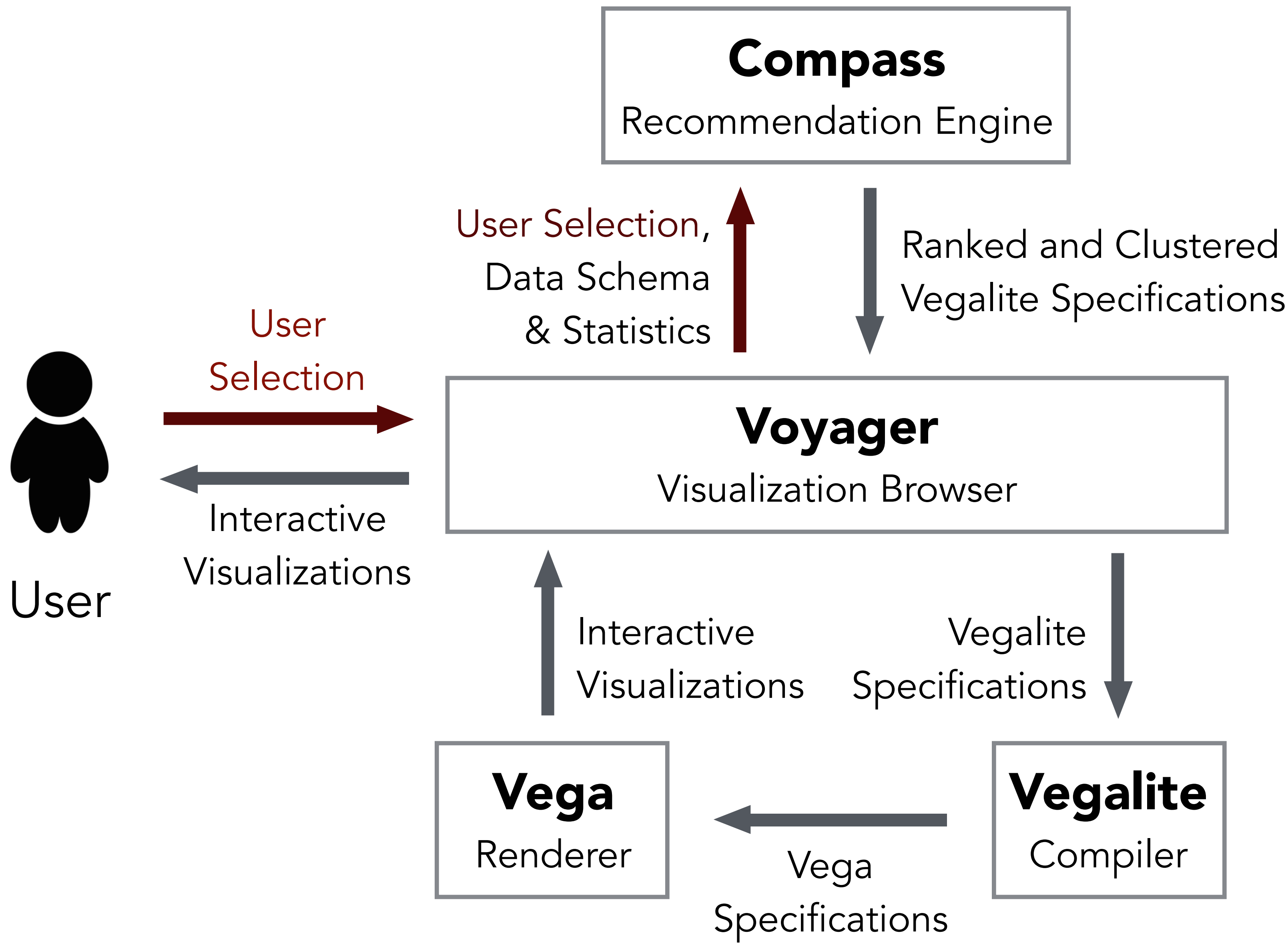
Compass
Recommendation Engine
Data Schema
& Statistics
Ranked and Clustered
Vegalite Specifications
Voyager
Visualization Browser
User
Vegalite
Specifications
Vegalite
Compiler


Compass
Recommendation Engine
Data Schema
& Statistics
Ranked and Clustered
Vegalite Specifications
User
Voyager
Visualization Browser
Vegalite
Specifications
Vega
Renderer
Vega
Specifications
Vegalite
Compiler



Compass
Recommendation Engine
Data Schema
& Statistics
Ranked and Clustered
Vegalite Specifications
User
Voyager
Visualization Browser
Interactive
Visualizations
Vegalite
Specifications
Vega
Renderer
Vega
Specifications
Vegalite
Compiler

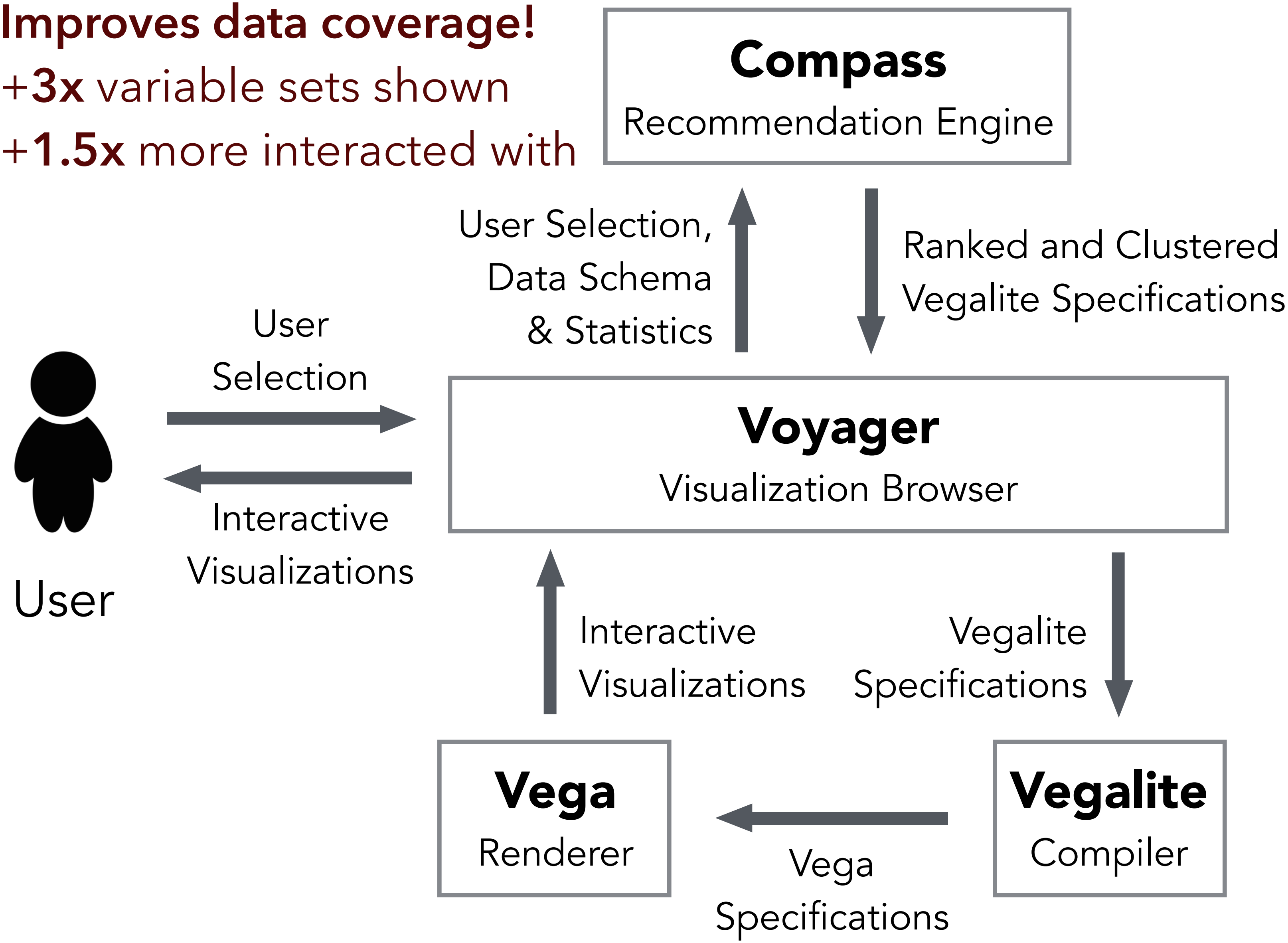

Compass
Recommendation Engine
Data Schema
& Statistics
Ranked and Clustered
Vegalite Specifications
User
Voyager
Visualization Browser
Interactive
Visualizations
Interactive
Visualizations
Vegalite
Specifications
Vega
Renderer
Vega
Specifications
Vegalite
Compiler

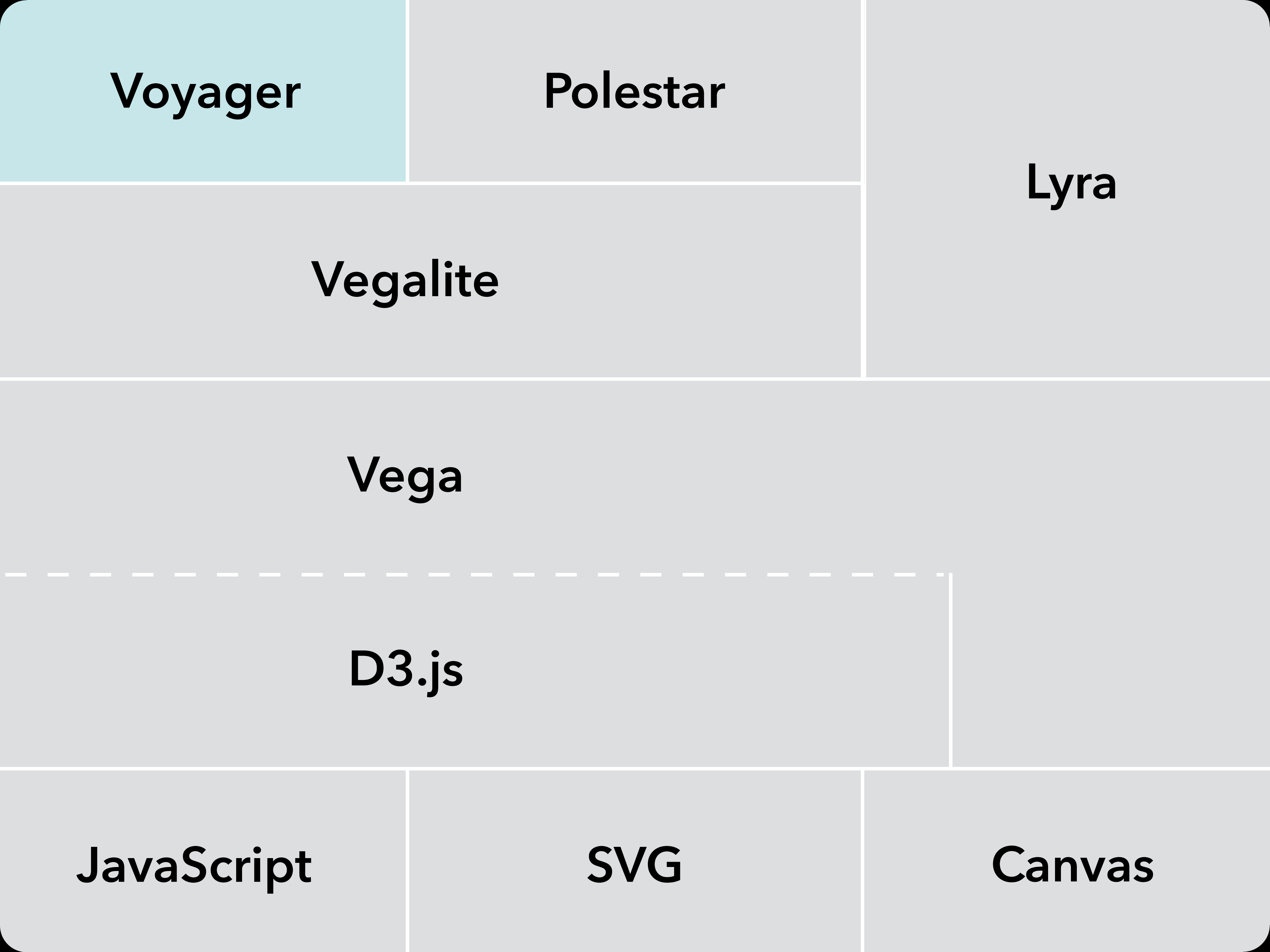

Compass
Recommendation Engine
User Selection,
Data Schema
& Statistics
Ranked and Clustered
Vegalite Specifications
User
Selection
Voyager
Visualization Browser
Interactive
Visualizations
User
Interactive
Visualizations
Vegalite
Specifications
Vega
Renderer
Vegalite
Compiler
Vega
Specifications

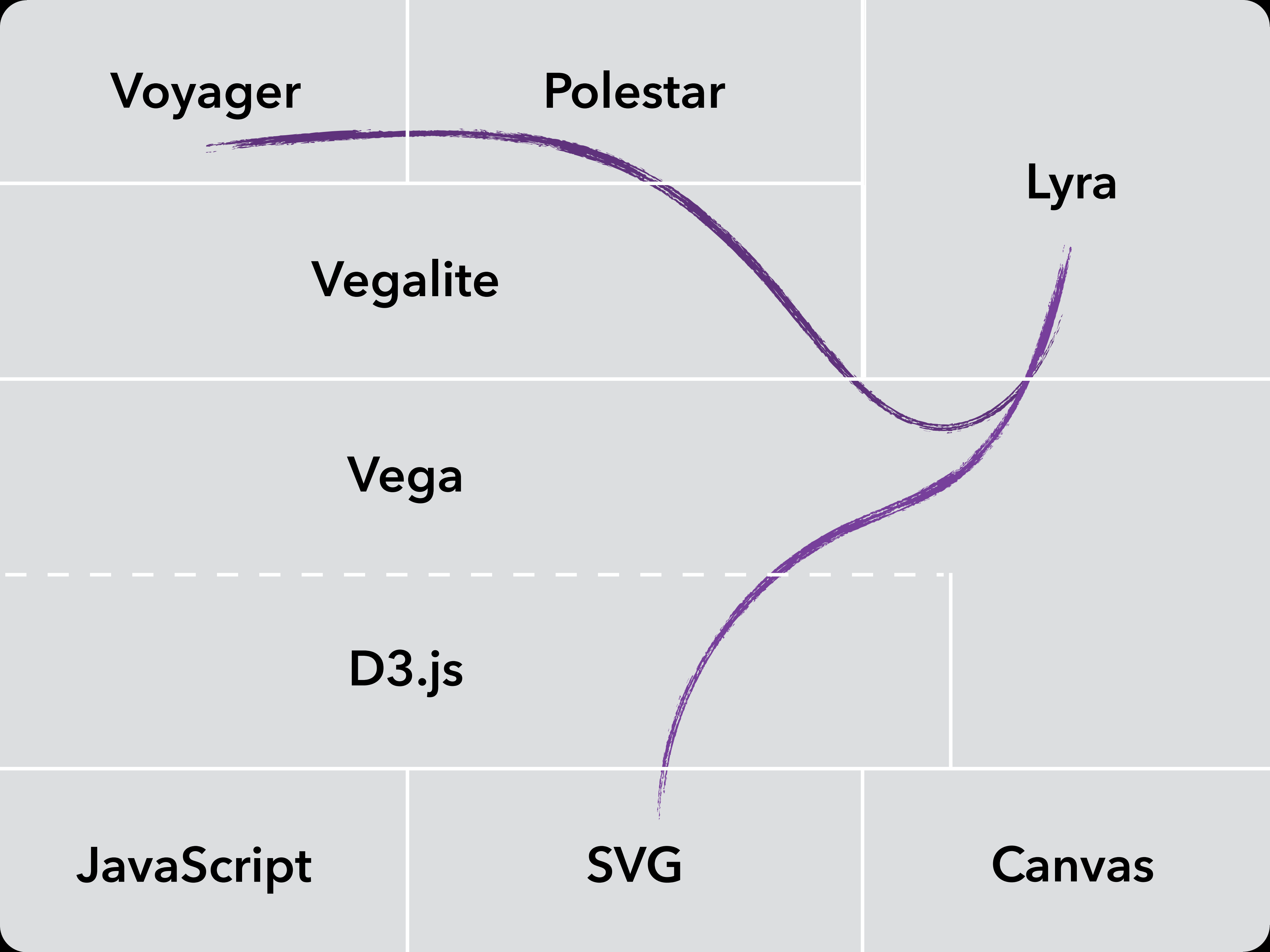
Improves data coverage!

+**3x** variable sets shown

+**1.5x** more interacted with

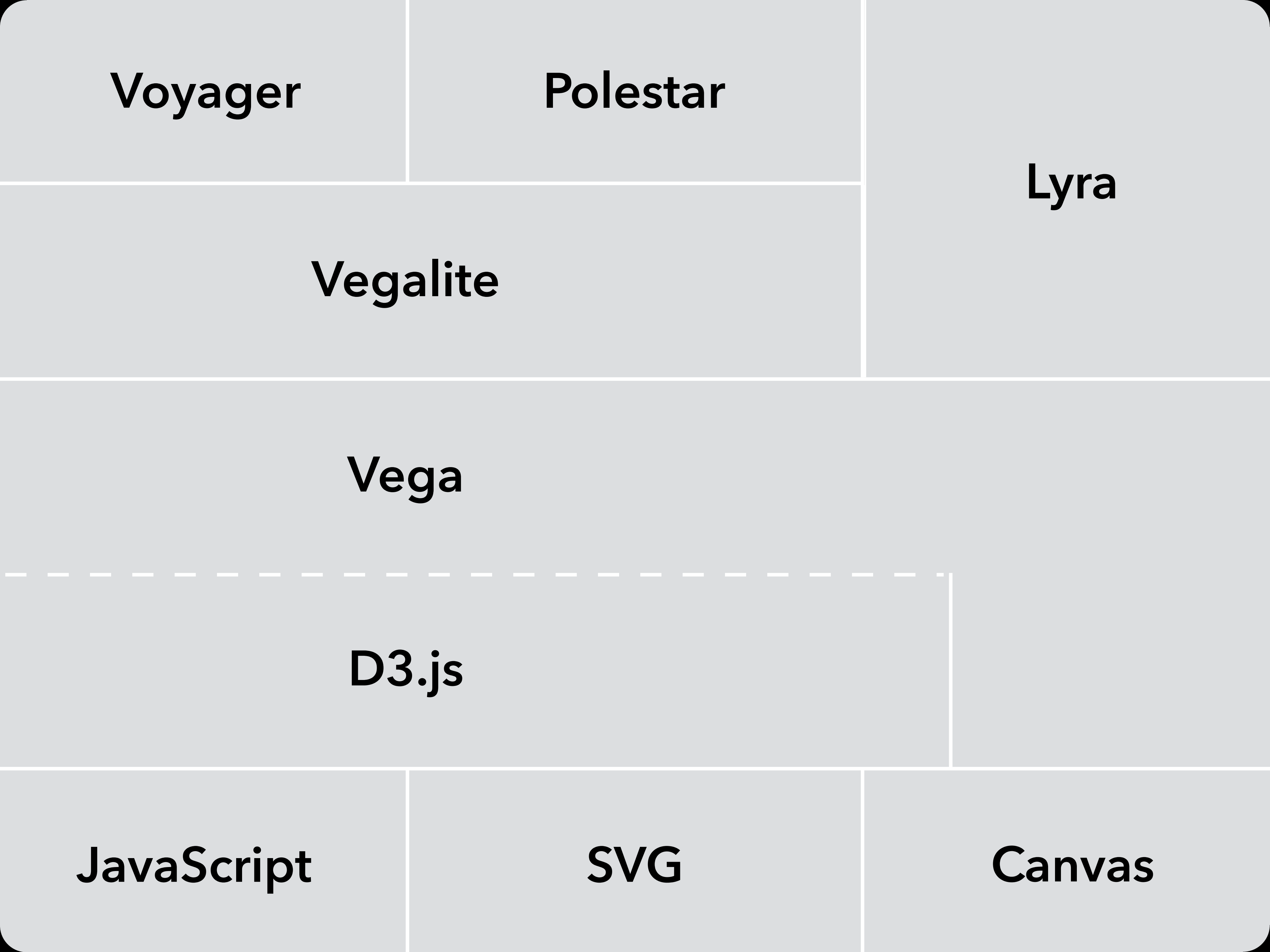


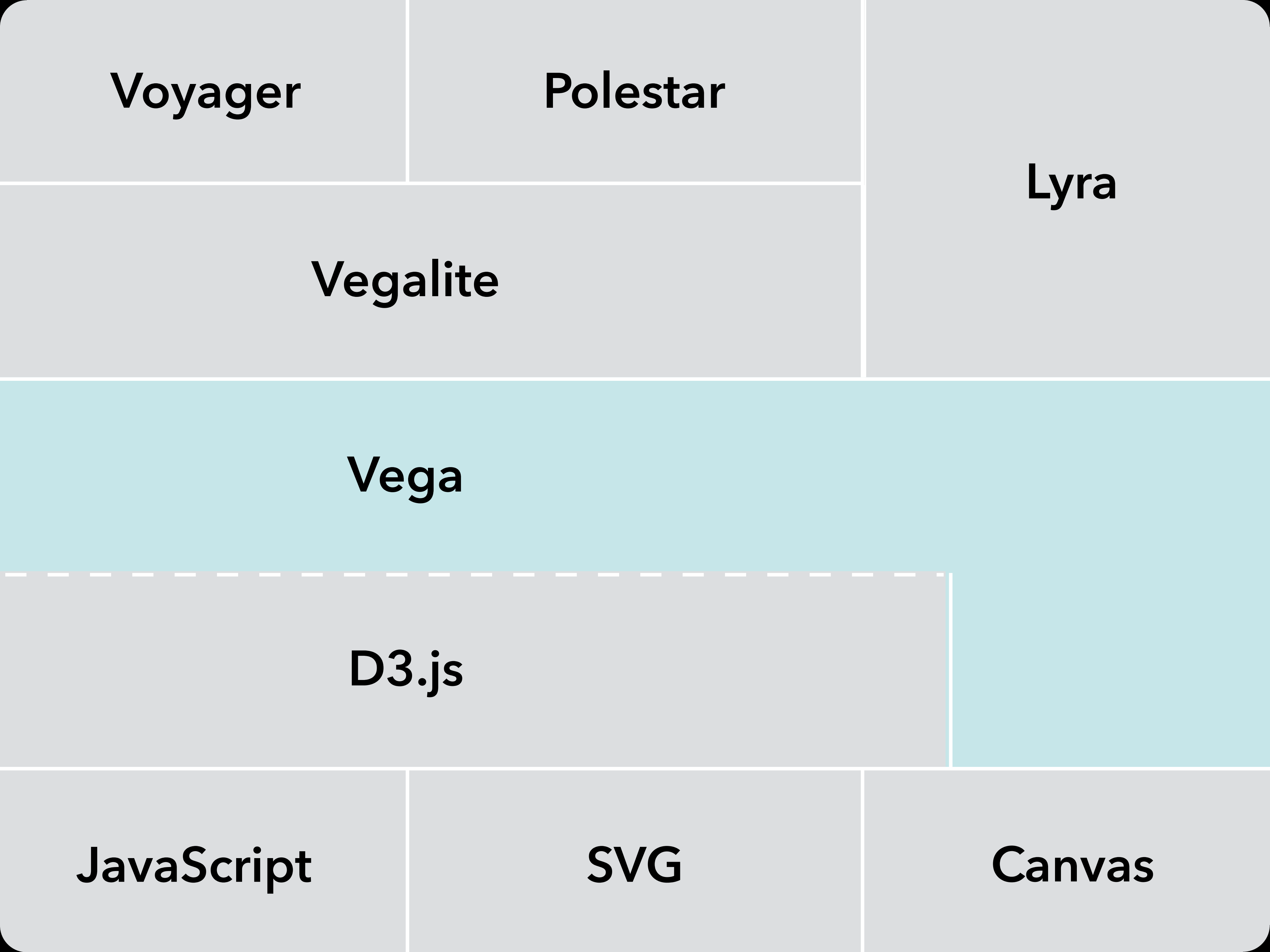

Voyager
Polestar
Lyra
Vegalite
Vega
D3.js
JavaScript
SVG
Canvas

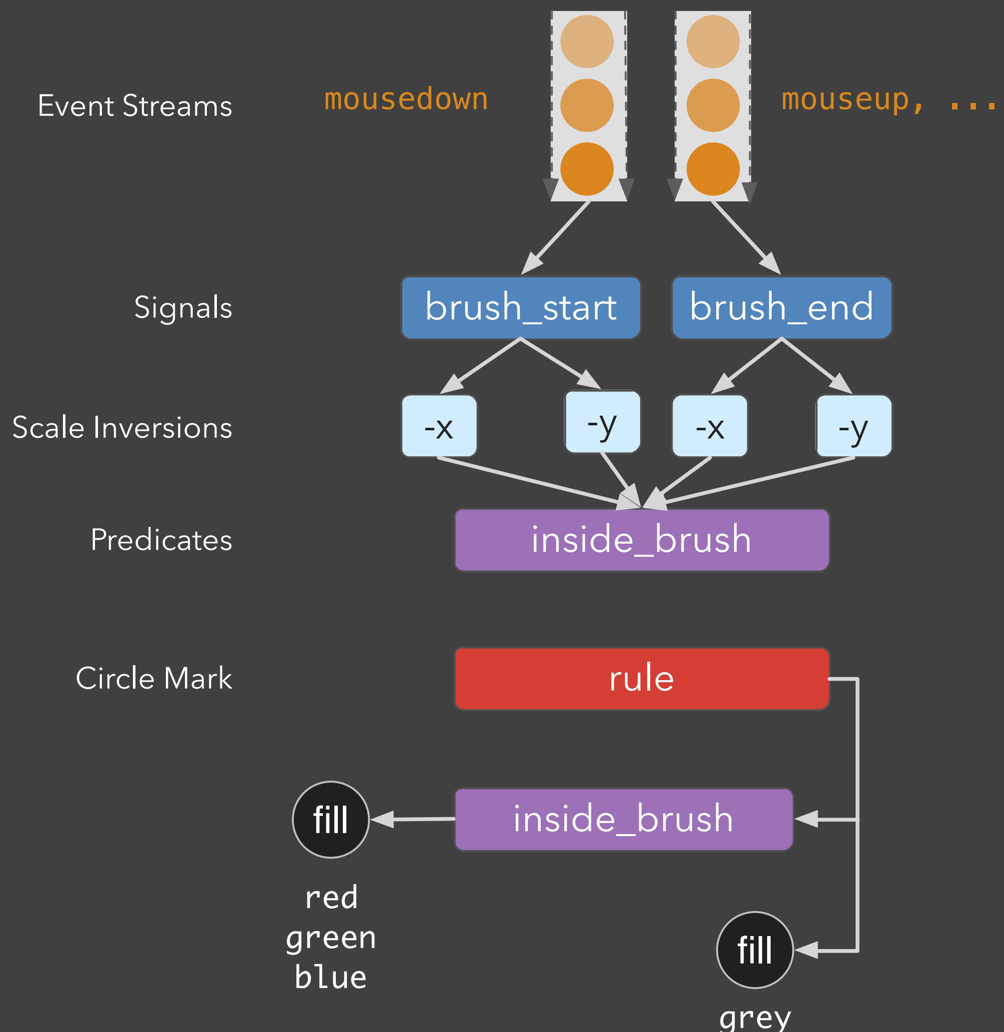

Voyager
Polestar
Lyra
Vegalite
Vega
D3.js
JavaScript
SVG
Canvas

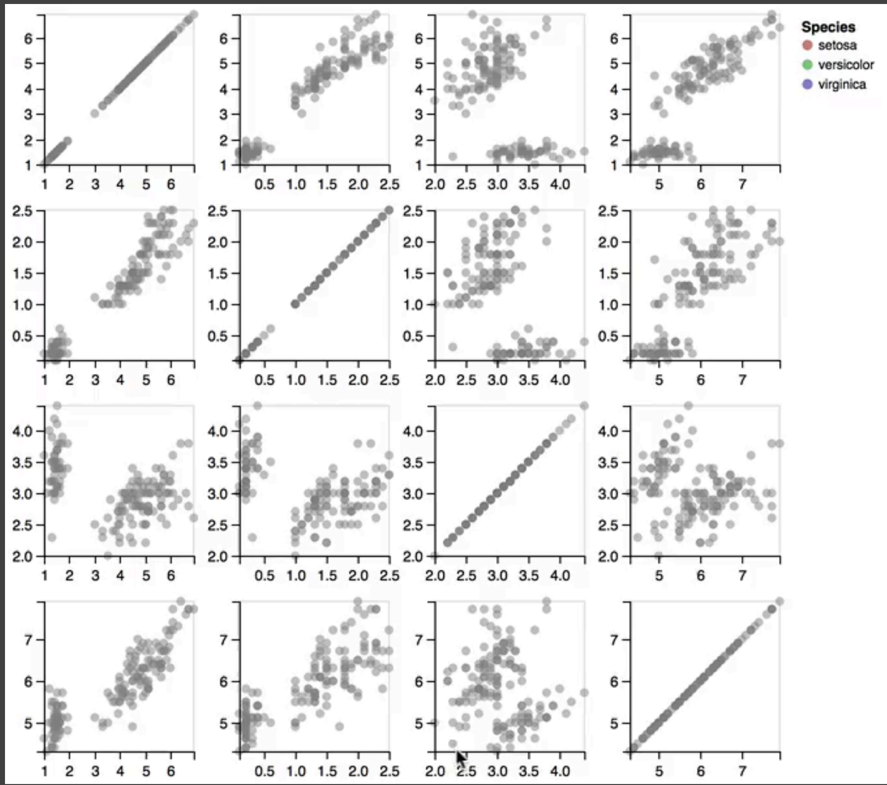
What about

interaction?


Voyager
Polestar
Lyra
Vegalite
Vega
D3.js
JavaScript
SVG
Canvas

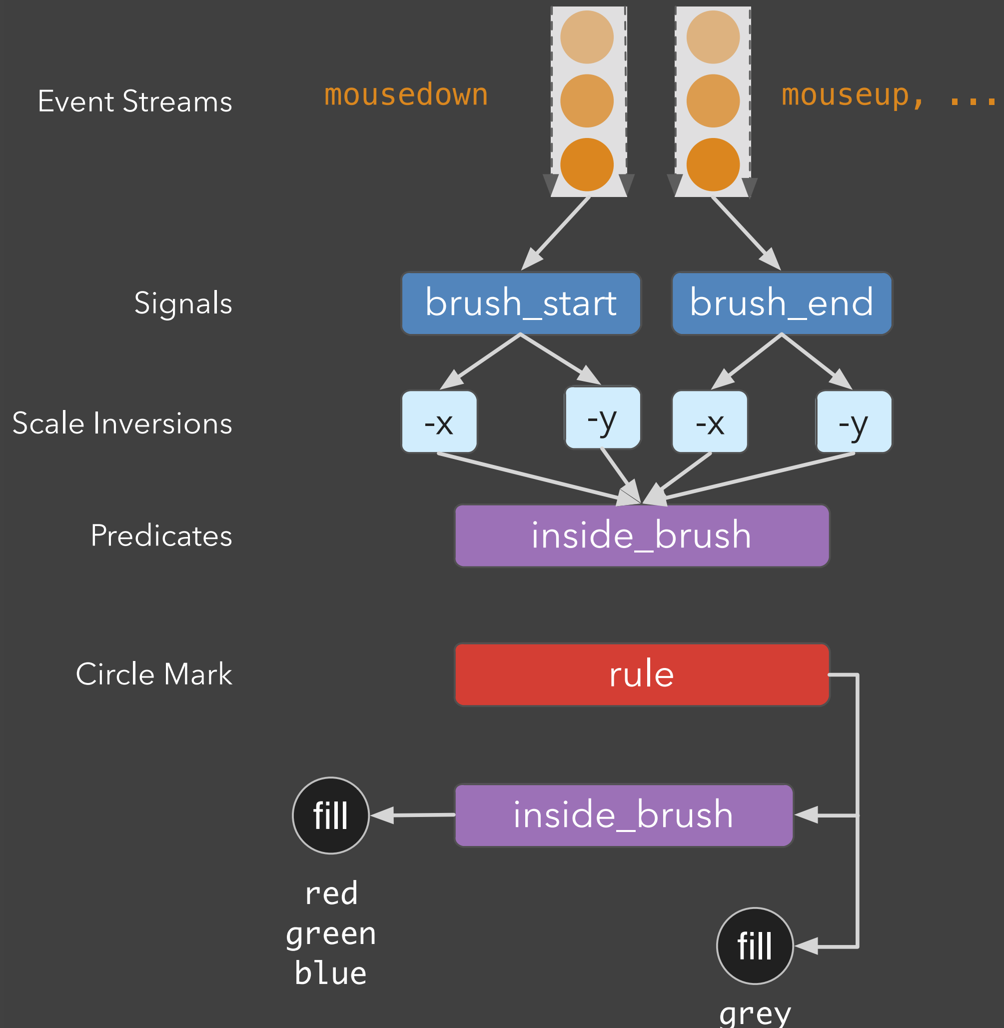

Voyager
Polestar
Lyra
Vegalite
Vega
D3.js
JavaScript
SVG
Canvas

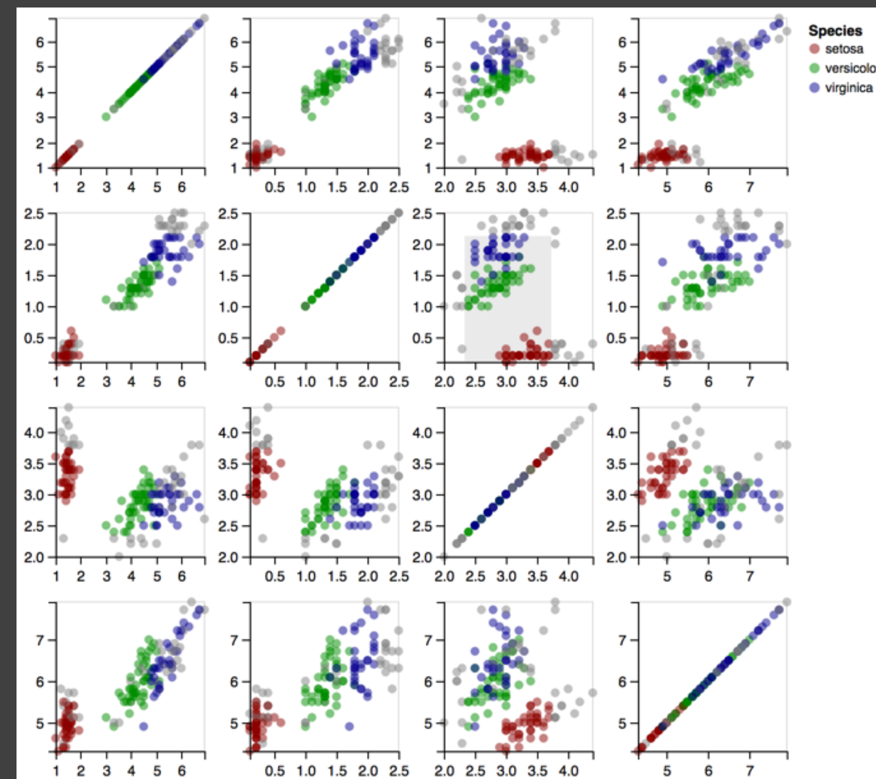




Reactive Vega

Satyanarayan et al. [UIST'14]





Key Insight: **Treat user input as first-class streaming data**

Adapt methods from functional reactive programming

Vega 2.0 ("Reactive Vega")

Single declarative model for specifying
visual encodings + **interaction techniques**

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JSON –> Reactive Dataflow Graph
Designed ground-up for **streaming data**
Performance matches or exceeds D3

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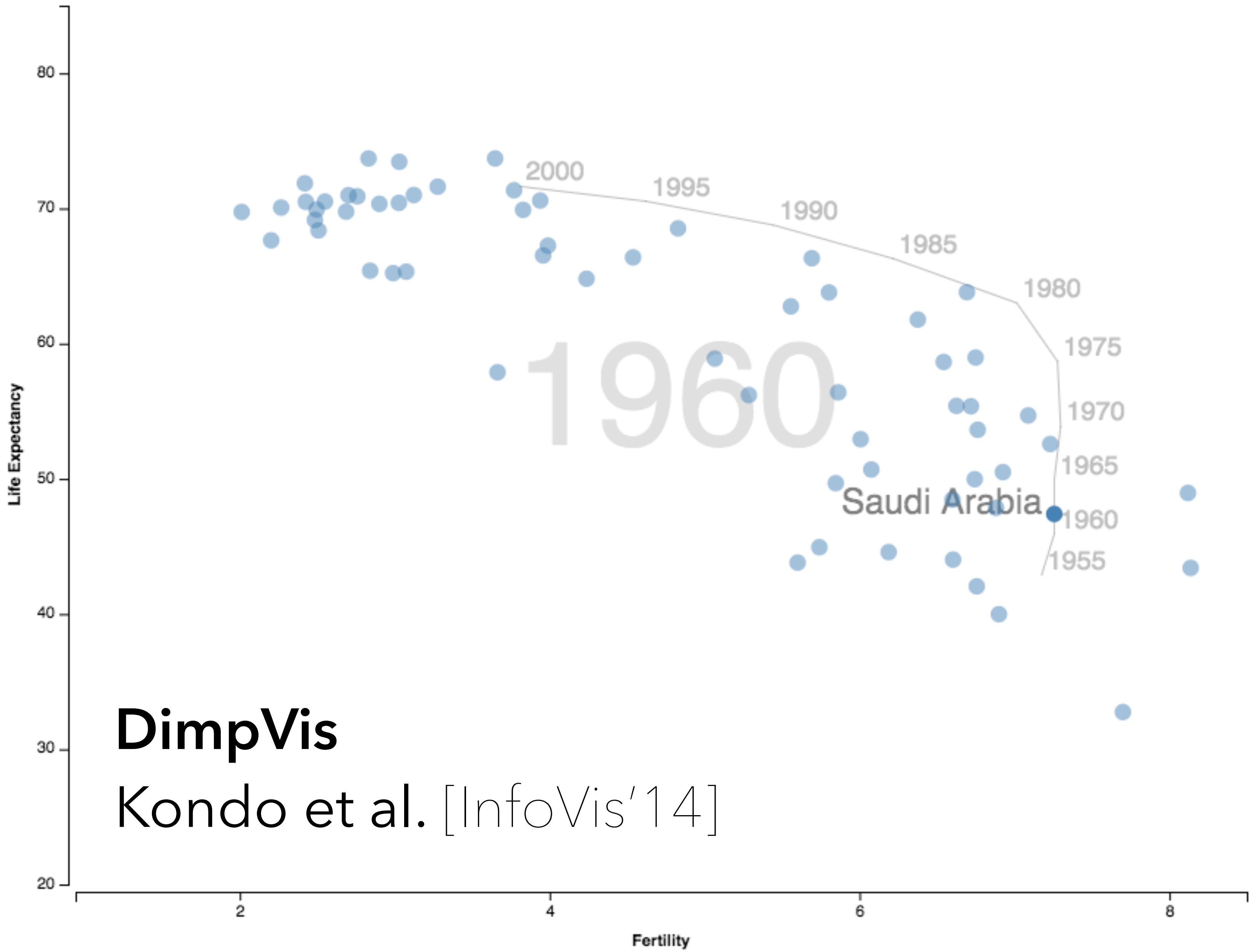
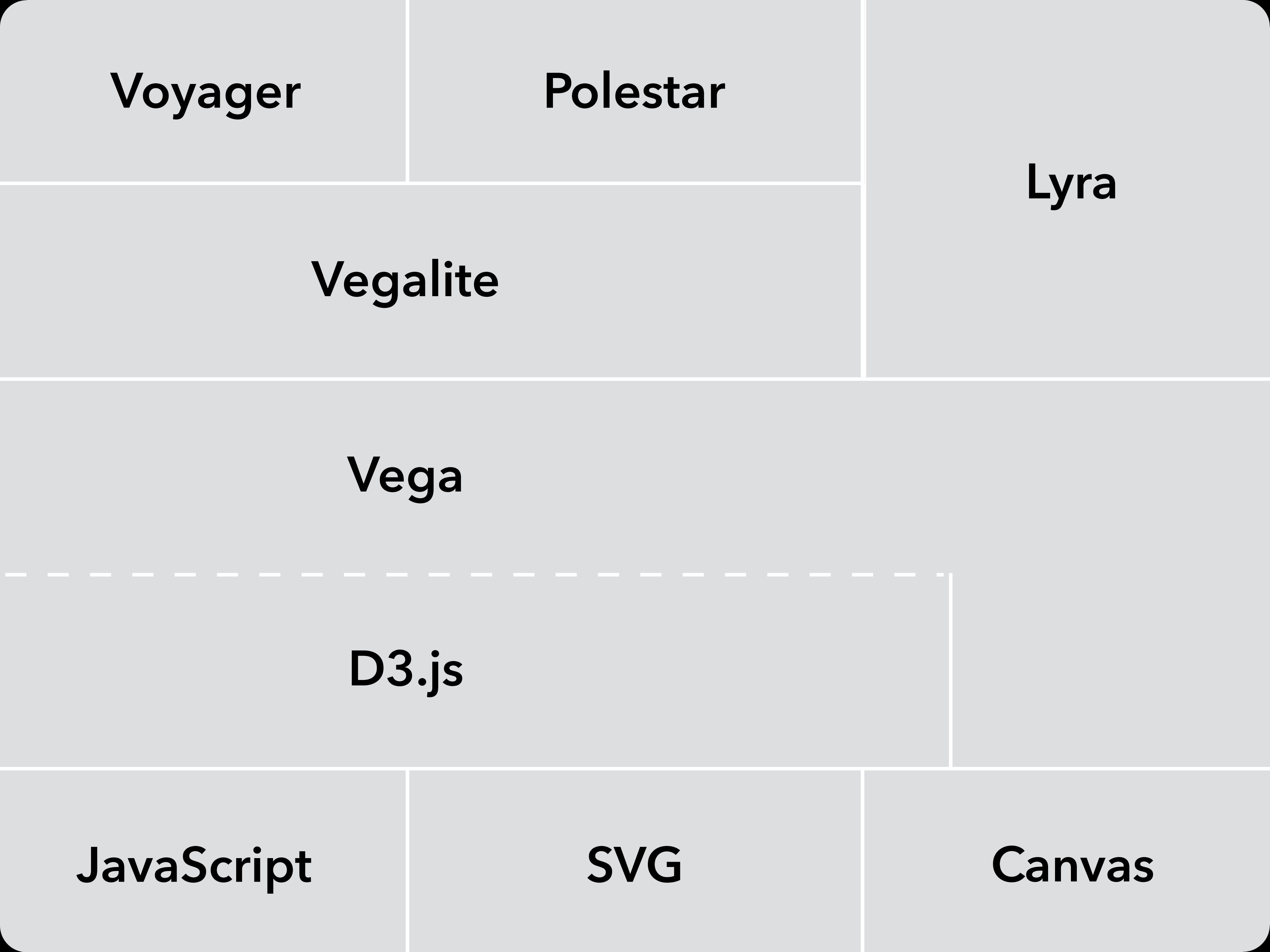
Portable
Client (*browser*) or server-side (*node.js*)
Pick your renderer: *Canvas*, *SVG*, …
Pick your input: *mouse*, *touch*, …



DimpVis

Kondo et al. [InfoVis'14]


Voyager
Polestar
Lyra
Vegalite
Vega
D3.js
JavaScript
SVG
Canvas

Open Challenges

Designing interactions interactively

How to convey + depict interactions?

Enhancing the “gallery” experience

Rapid assessment of multiple graphics

Embedding large views in small spaces?

Improving visualization recommenders

Learning from users, domain adaptation

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Debugging, debugging, debugging…