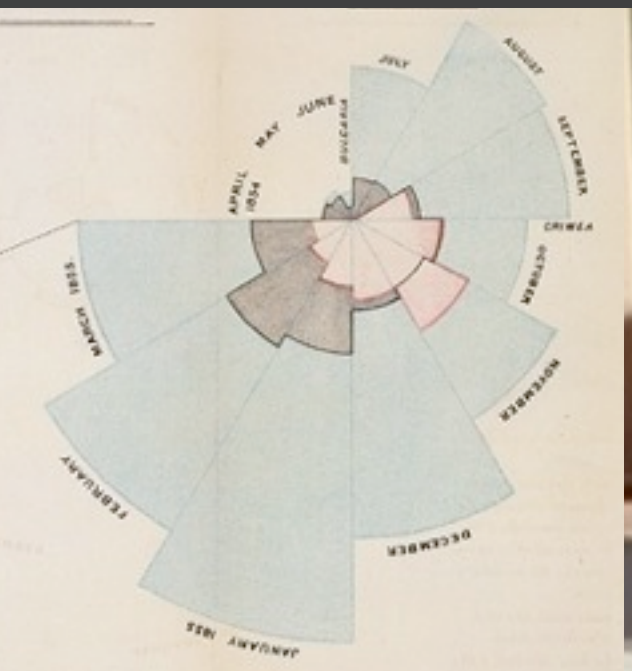
CSE512 :: 28 Jan 2014

Visualization Tools



Jeffrey Heer University of Washington

How do people create visualizations?

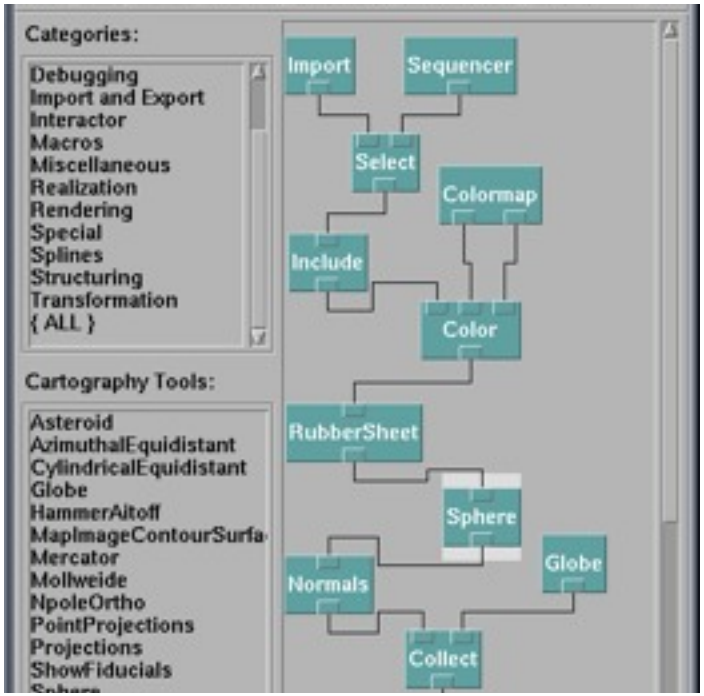


Chart Typology

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

OpenGL, Java2D, GDI+, Processing

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();
  }
}
```

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http://processing.org


US Air Traffic, Aaron Koblin

Graphics APIs

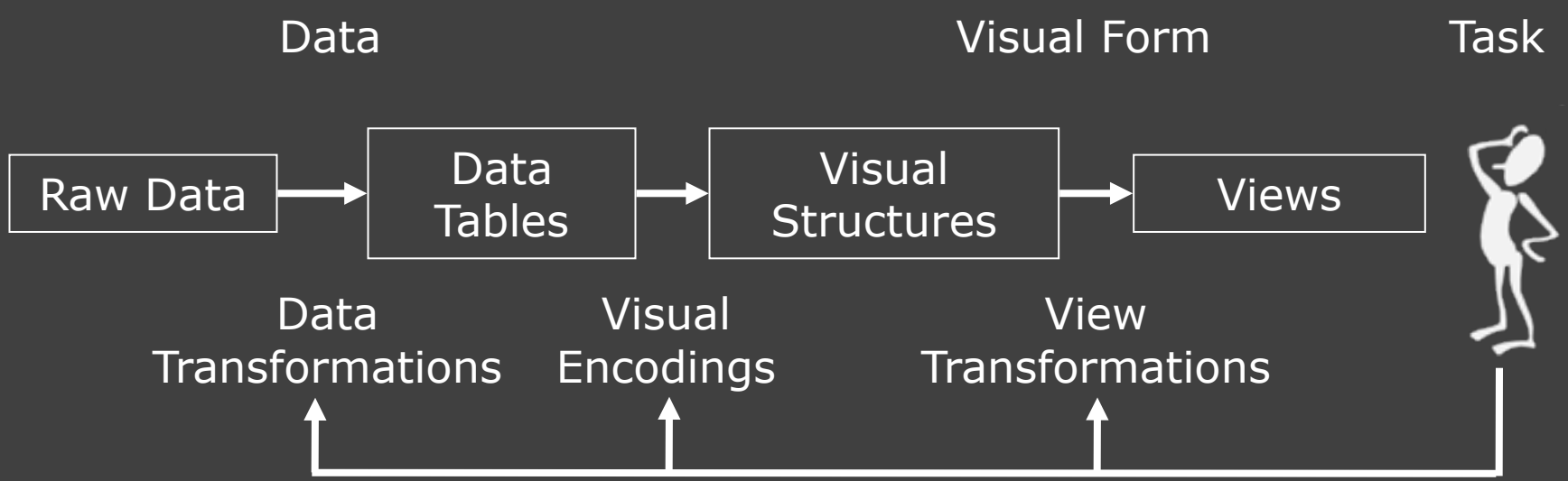
OpenGL, Java2D, GDI+, Processing

Component Model Architectures

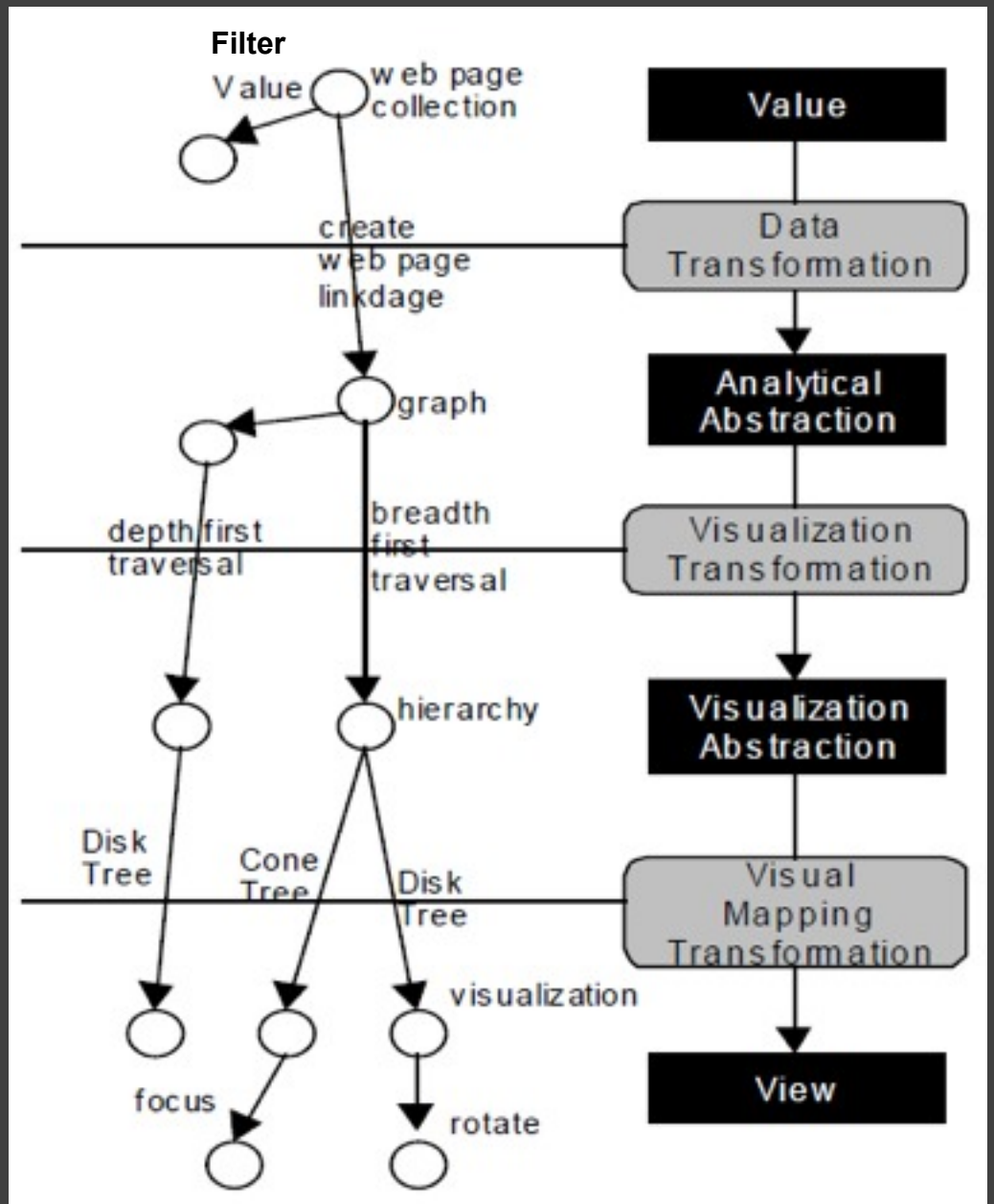
Prefuse, Flare, Improvise

Graphics APIs

OpenGL, Java2D, GDI+, Processing


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

Data State Model [Chi 98]



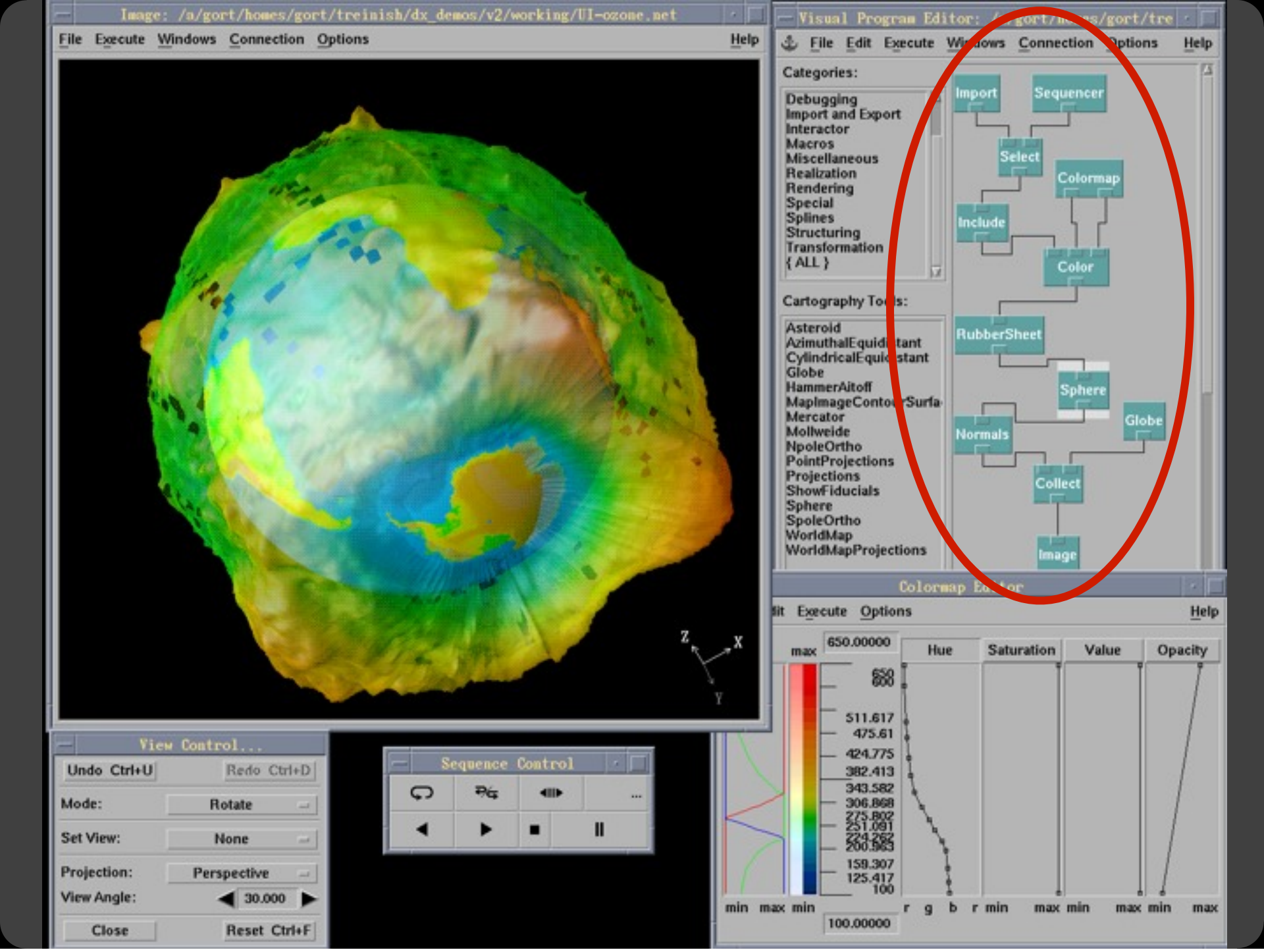
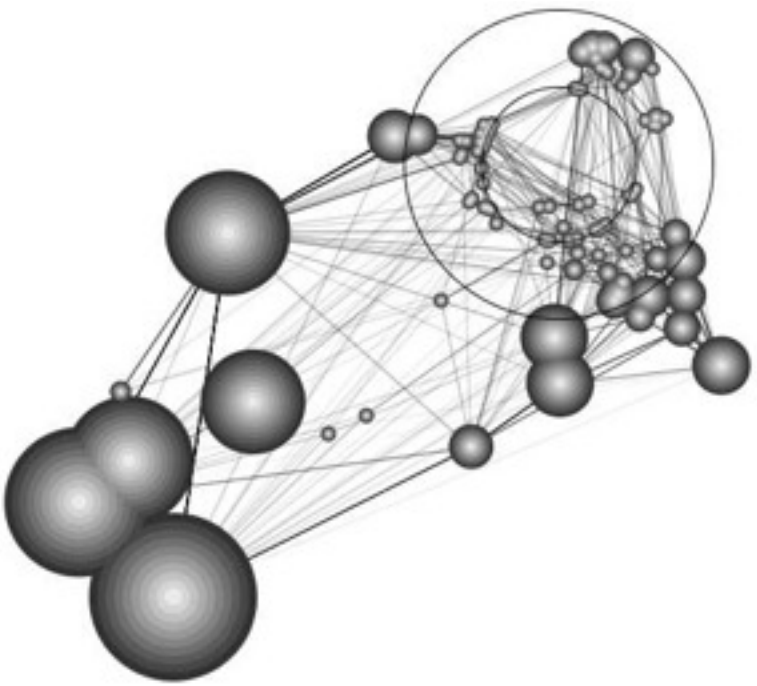


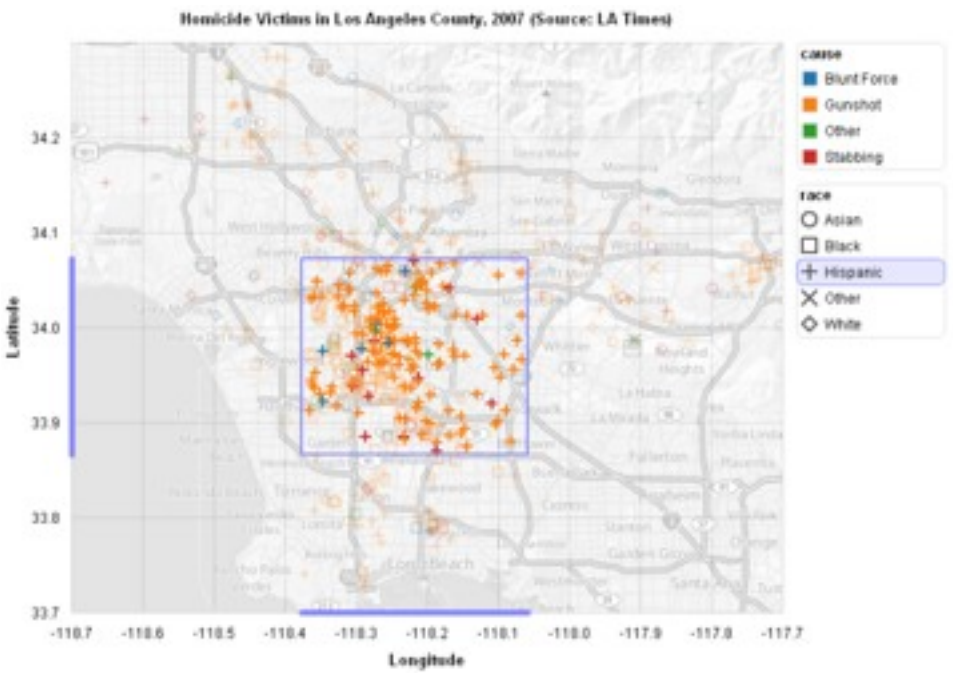
Image: /a/gort/homes/gort/treinish/dx_demos/v2/working/UI-ozone.net
File Execute Windows Connection Options Help
Visual Program Editor:
File Edit Execute Windows Connection Options Help
Categories:
Debugging
Import and Export
Interactor
Macros
Miscellaneous
Realization
Rendering
Special
Splines
Structuring
Transformation
{ ALL }
Cartography Tools:
Asteroid
AzimuthalEquidistant
CylindricalEquidistant
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
Colormap Editor
File Execute Options Help
max
650.00000
600
511.617
475.61
424.775
382.413
343.582
306.868
275.802
251.091
224.252
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
Z
X
Y

Prefuse & Flare

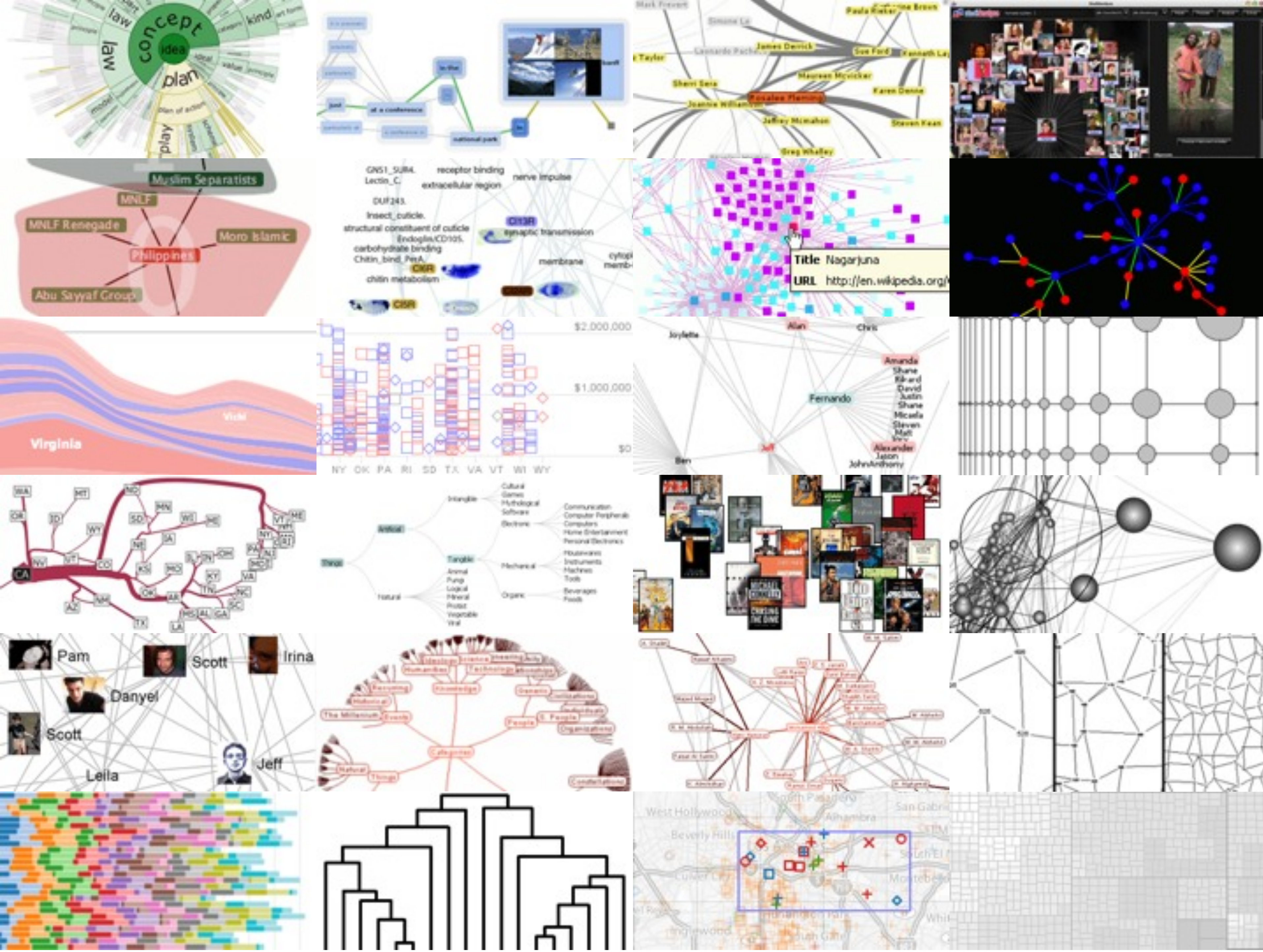
Operator-based toolkits for visualization design
Vis = (Input Data → Visual Objects) + Operators



Prefuse (http://prefuse.org)



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


concept
idea
plan
law
kind
play
Muslim Separatists
MNLF
MNLF Renegade
Moro Islamic
Philippines
Abu Sayyaf Group
Title Nagarjuna
URL http://en.wikipedia.org/
Virginia
$2,000,000
$1,000,000
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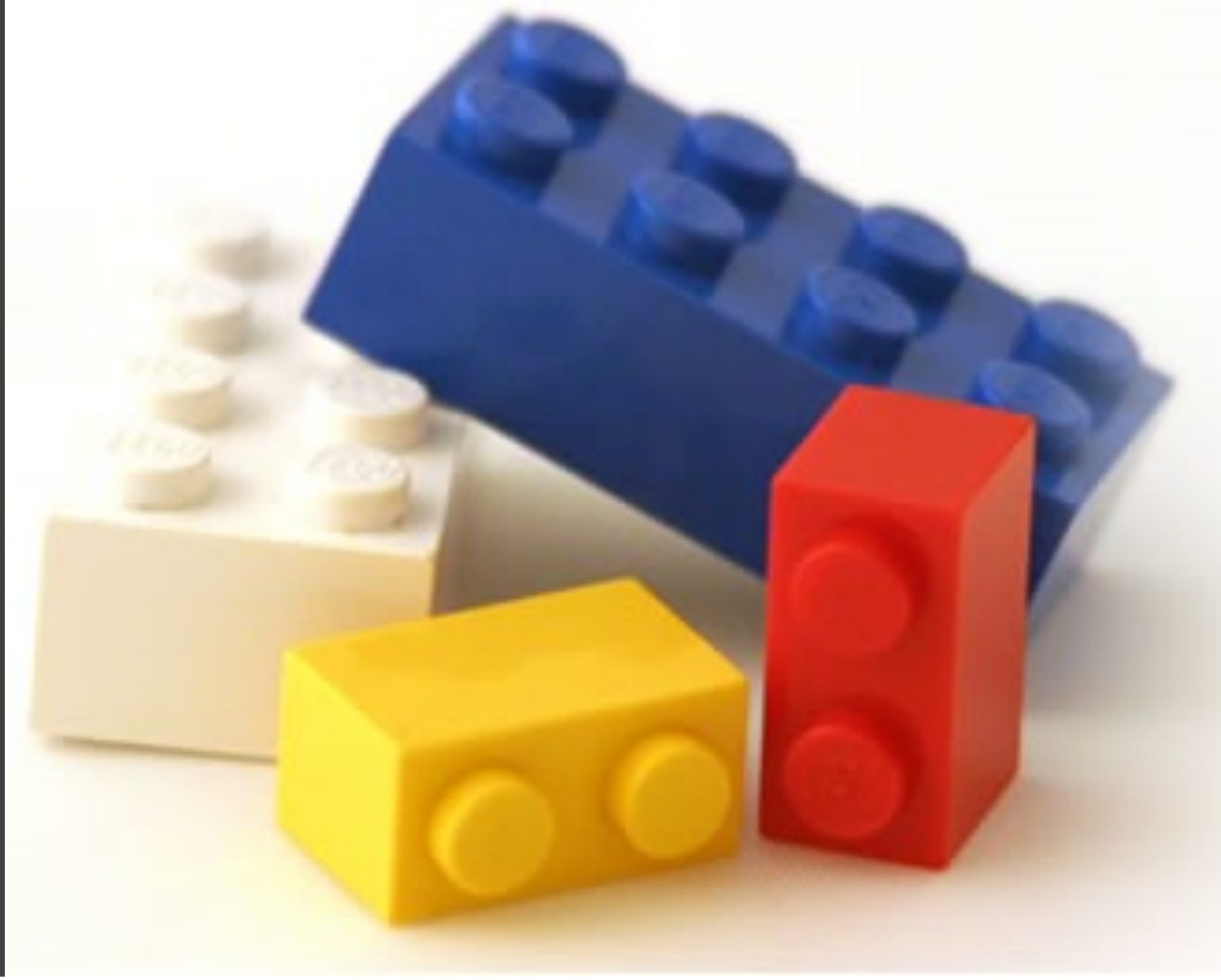
NY OK PA RI SD TX VA VT WI WY
Fernando
Pam
Scott
Irina
Danyel
Scott
Leila
Jeff



Component Model Architectures

Prefuse, Flare, Improvise

Graphics APIs

OpenGL, Java2D, GDI+, Processing

Chart Typologies

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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

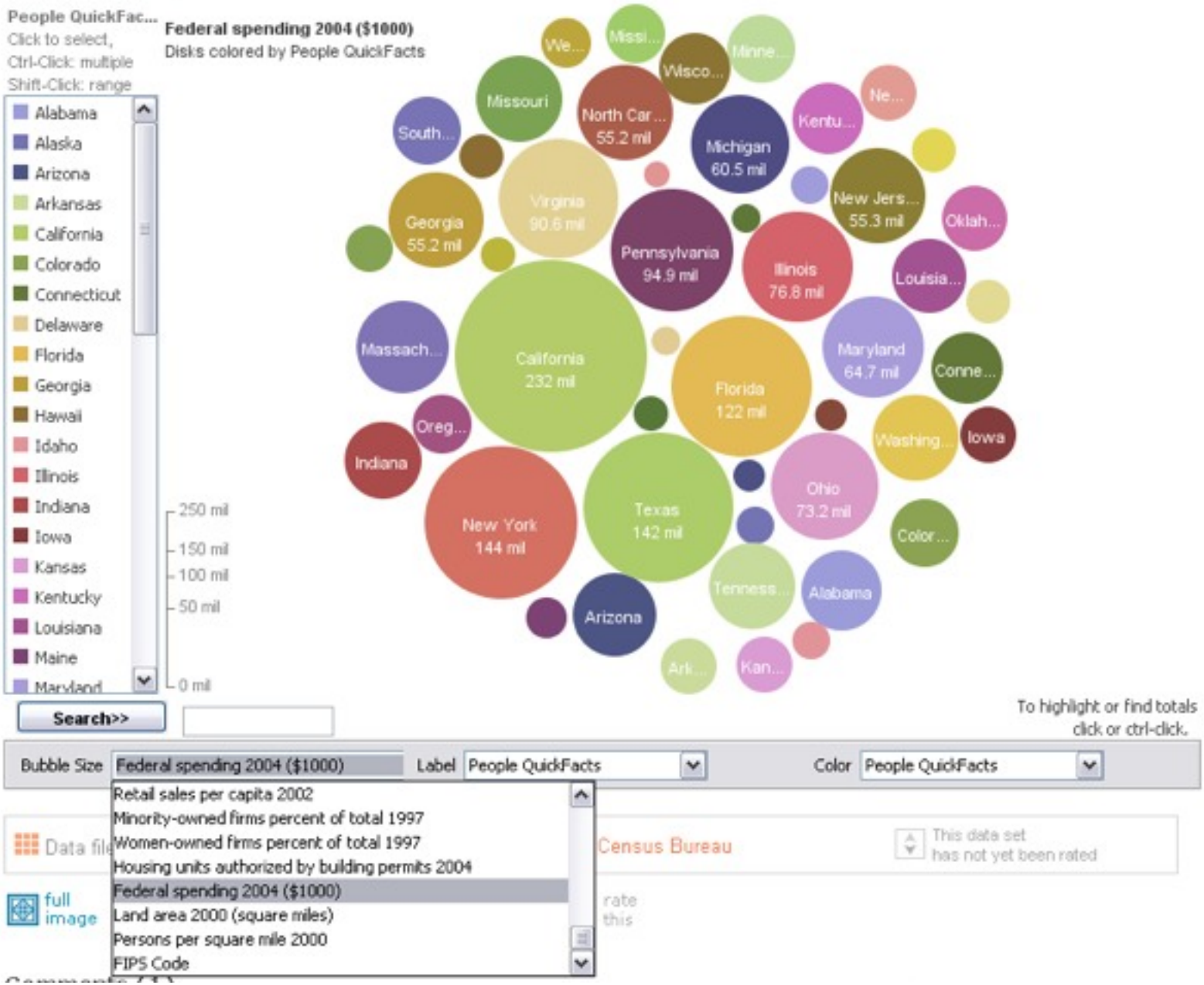
Block Histogram

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



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 Hanted 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*

Chart Typologies

Excel, Many Eyes, Google Charts

Component Model Architectures

Prefuse, Flare, Improvise

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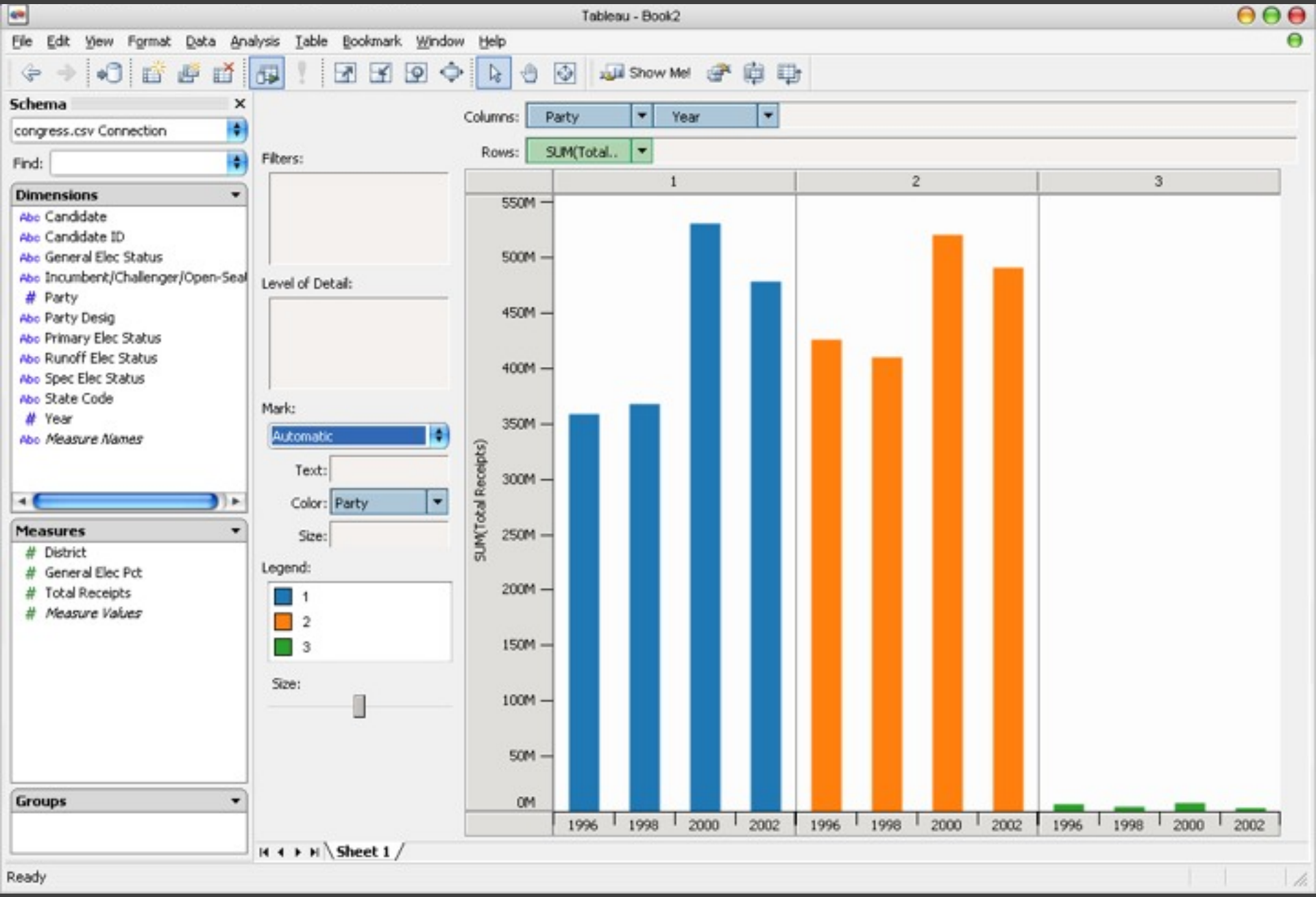
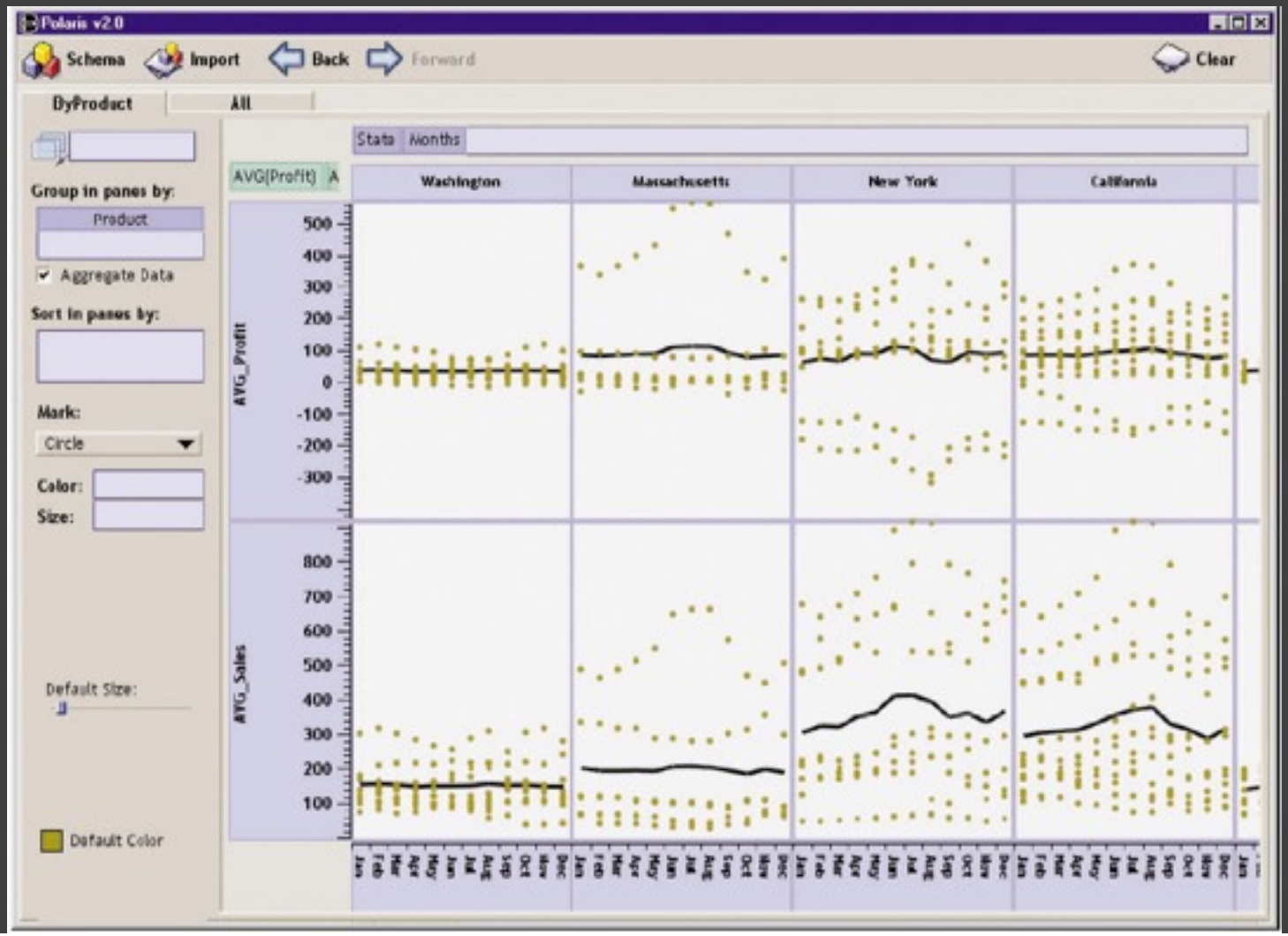


Tableau - Book2
File Edit View Format Data Analysis Table Bookmark Window Help
Show Me!
Schema
congress.csv Connection
Find:
Dimensions
Abc Candidate
Abc Candidate ID
Abc General Elec Status
Abc Incumbent/Challenger/Open-Seat
Party
Abc Party Desig
Abc Primary Elec Status
Abc Runoff Elec Status
Abc Spec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

Polaris

Research at Stanford by Stolte, Tang, and Hanrahan.



Polaris / Tableau Approach

Insight: can simultaneously specify both database queries and visualization

Choose data, then visualization, not vice versa

Use smart defaults for visual encodings

More recently: automate visualization design

Specifying Table Configurations

Operands are the database fields

- Each operand interpreted as a set {...}
- Quantitative and Ordinal fields treated differently

Three operators:

- **concatenation** (**+**)
- **cross product** (**x**)
- **nest** (**/**)

Table Algebra: Operands

Ordinal fields: interpret domain as a set that partitions table into rows and columns.

Quarter = {(Qtr1),(Qtr2),(Qtr3),(Qtr4)} →

Qtr1	Qtr2	Qtr3	Qtr4
95892	101760	105282	98225

Quantitative fields: treat domain as single element set and encode spatially as axes:

Profit = {(Profit[-410,650])} →

Concatenation (+) Operator

Ordered union of set interpretations

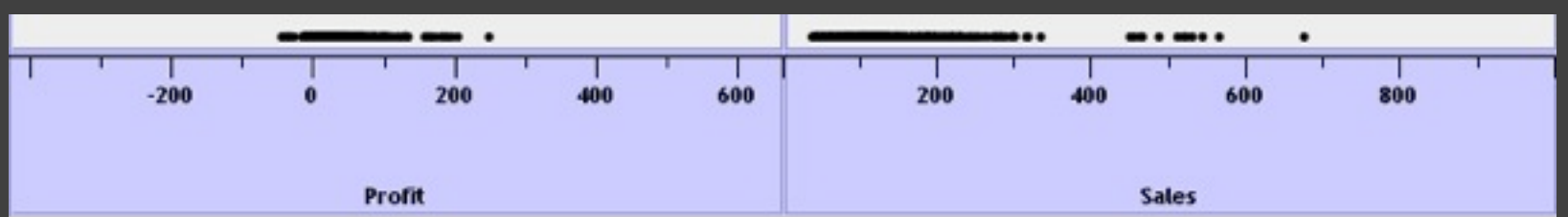
Quarter + Product Type

= {(Qtr1),(Qtr2),(Qtr3),(Qtr4)} + {(Coffee), (Espresso)}

= {(Qtr1),(Qtr2),(Qtr3),(Qtr4),(Coffee),(Espresso)}

Qtr1	Qtr2	Qtr3	Qtr4	Coffee	Espresso
48	59	57	53	151	21

Profit + Sales = {(Profit[-310,620]),(Sales[0,1000])}



Cross (x) Operator

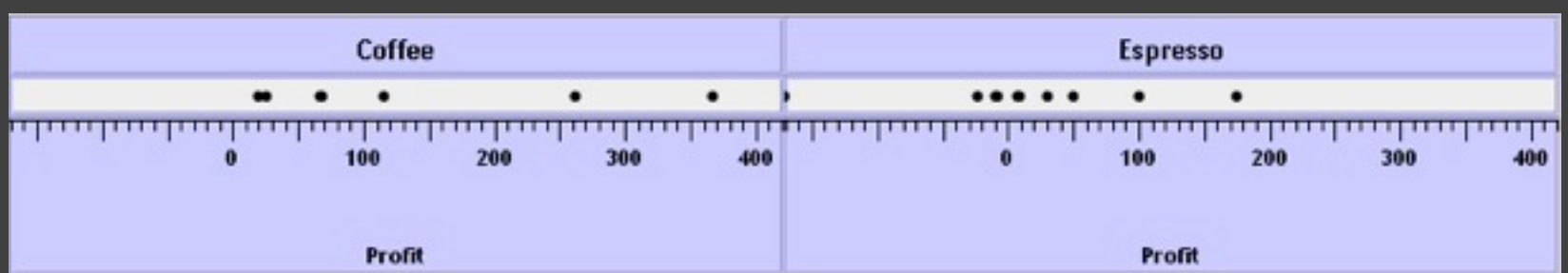
Cross-product of set interpretations

Quarter x Product Type

= {(Qtr1,Coffee), (Qtr1, Tea), (Qtr2, Coffee), (Qtr2, Tea), (Qtr3, Coffee), (Qtr3, Tea), (Qtr4, Coffee), (Qtr4,Tea)}

Qtr1		Qtr2		Qtr3		Qtr4	
Coffee	Espresso	Coffee	Espresso	Coffee	Espresso	Coffee	Espresso
131	19	160	20	178	12	134	33

Product Type x Profit =



Nest (/) Operator

Cross-product filtered by existing records

Quarter x Month

creates twelve entries for each quarter. i.e., (Qtr1, December)

Quarter / Month

creates three entries per quarter based on tuples in database (not semantics)

Table Algebra

The operators (+, x, /) and operands (O, Q) provide an *algebra* for tabular visualization.

Algebraic statements are then mapped to:

Queries - selection, projection, group-by aggregation

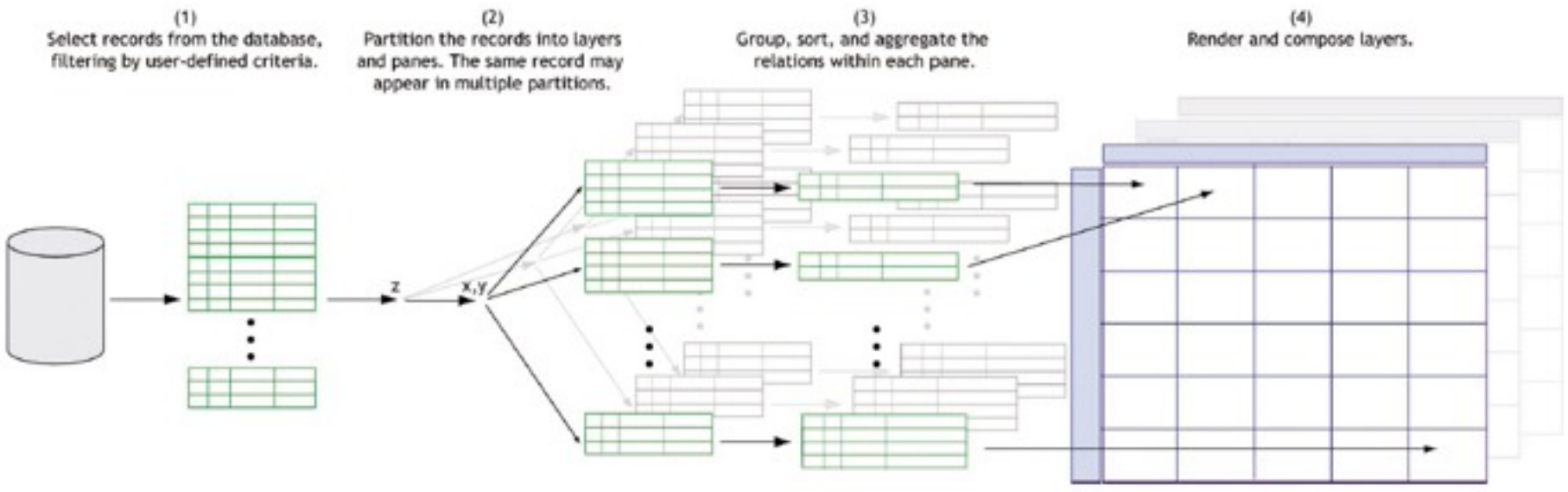
Visualizations - trellis plot partitions, visual encodings

In Tableau, users make statements via drag-and-drop

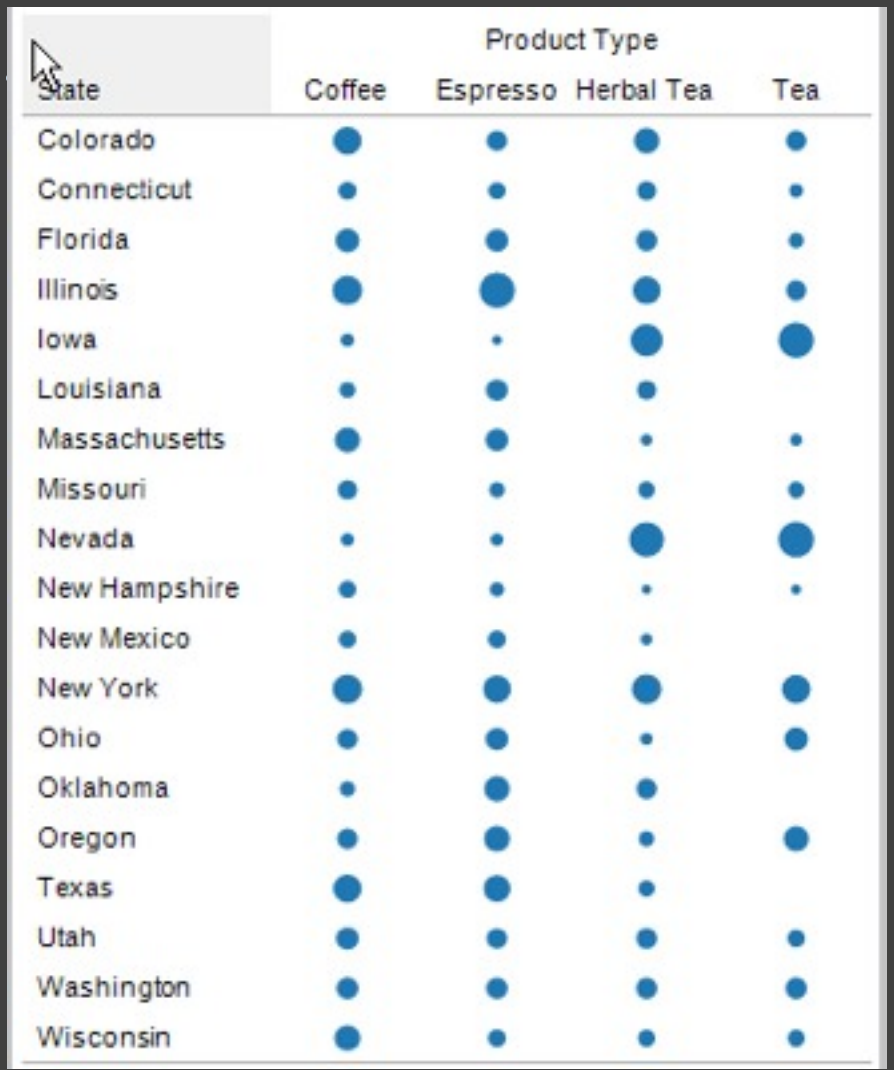
Note that this specifies operands NOT operators!

Operators are inferred by data type (O, Q)

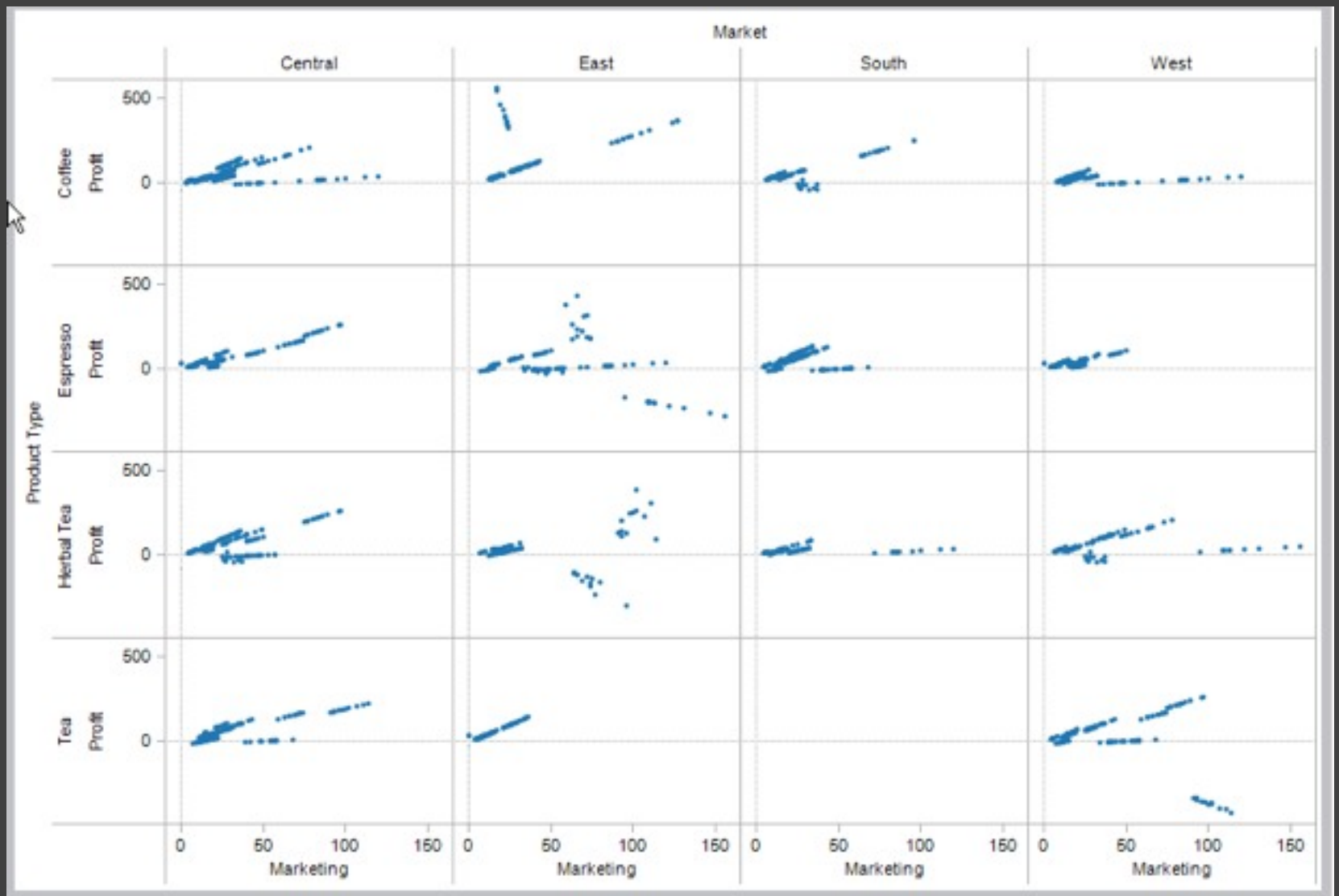
Querying the Database



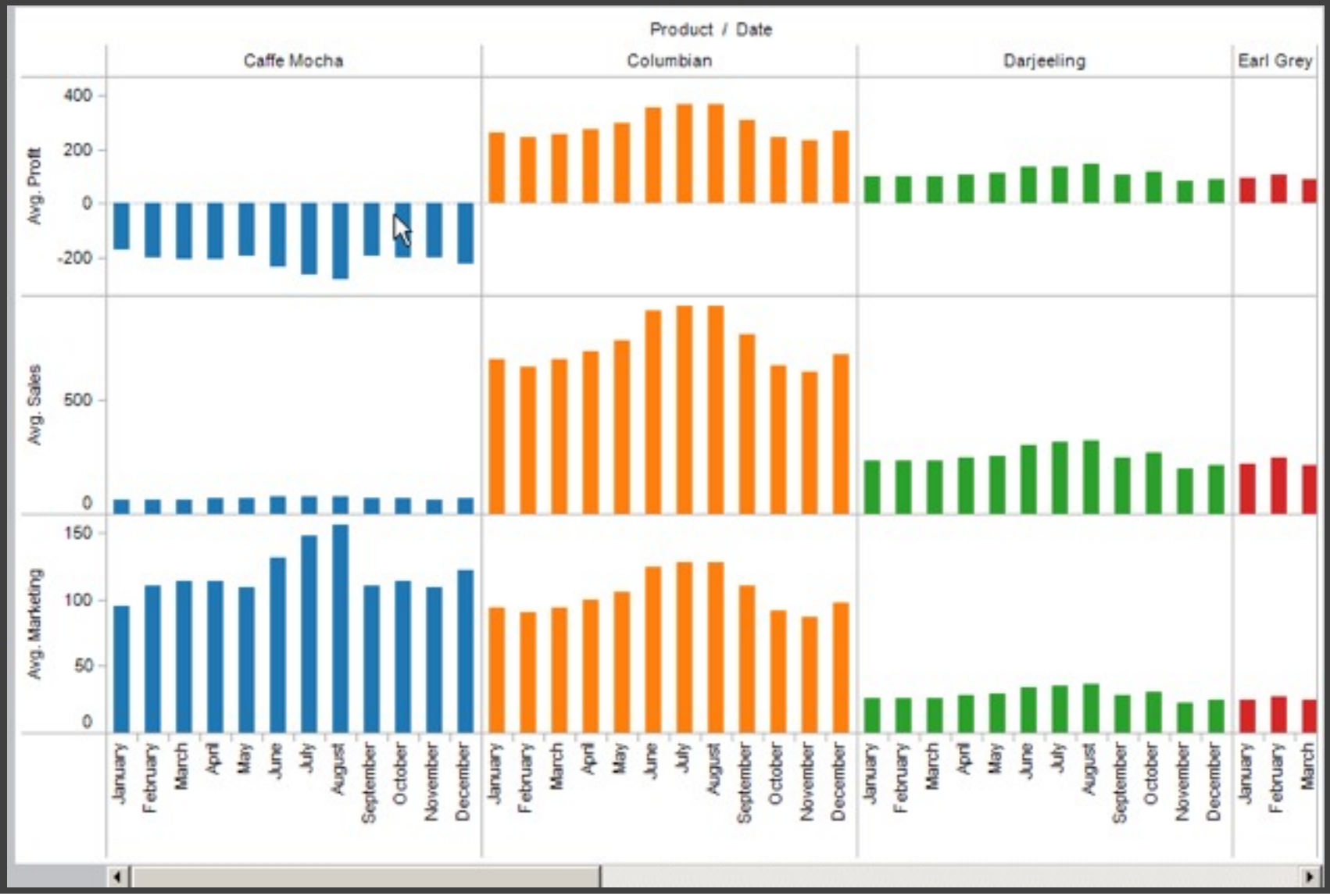
Ordinal - Ordinal

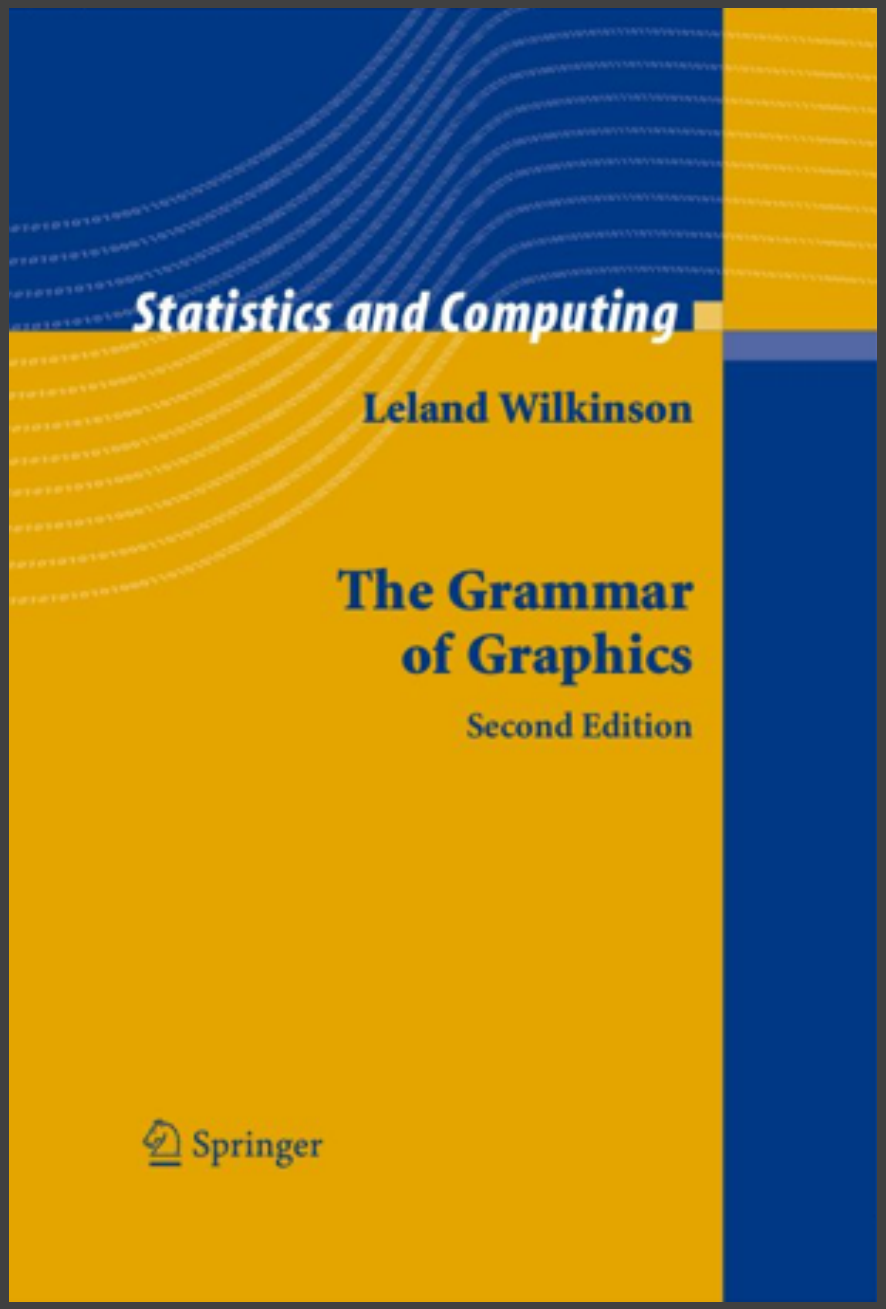


Quantitative - Quantitative



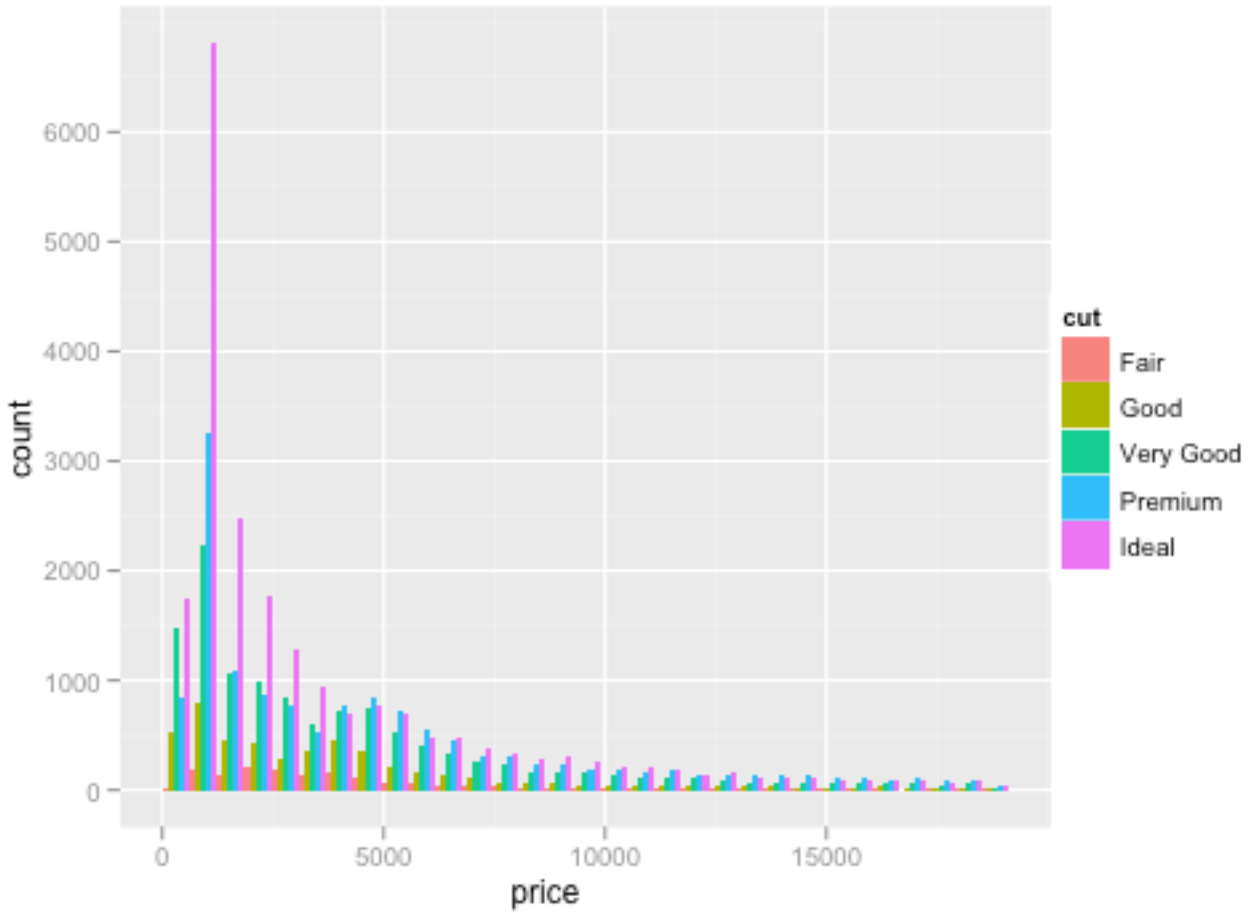
Ordinal - Quantitative



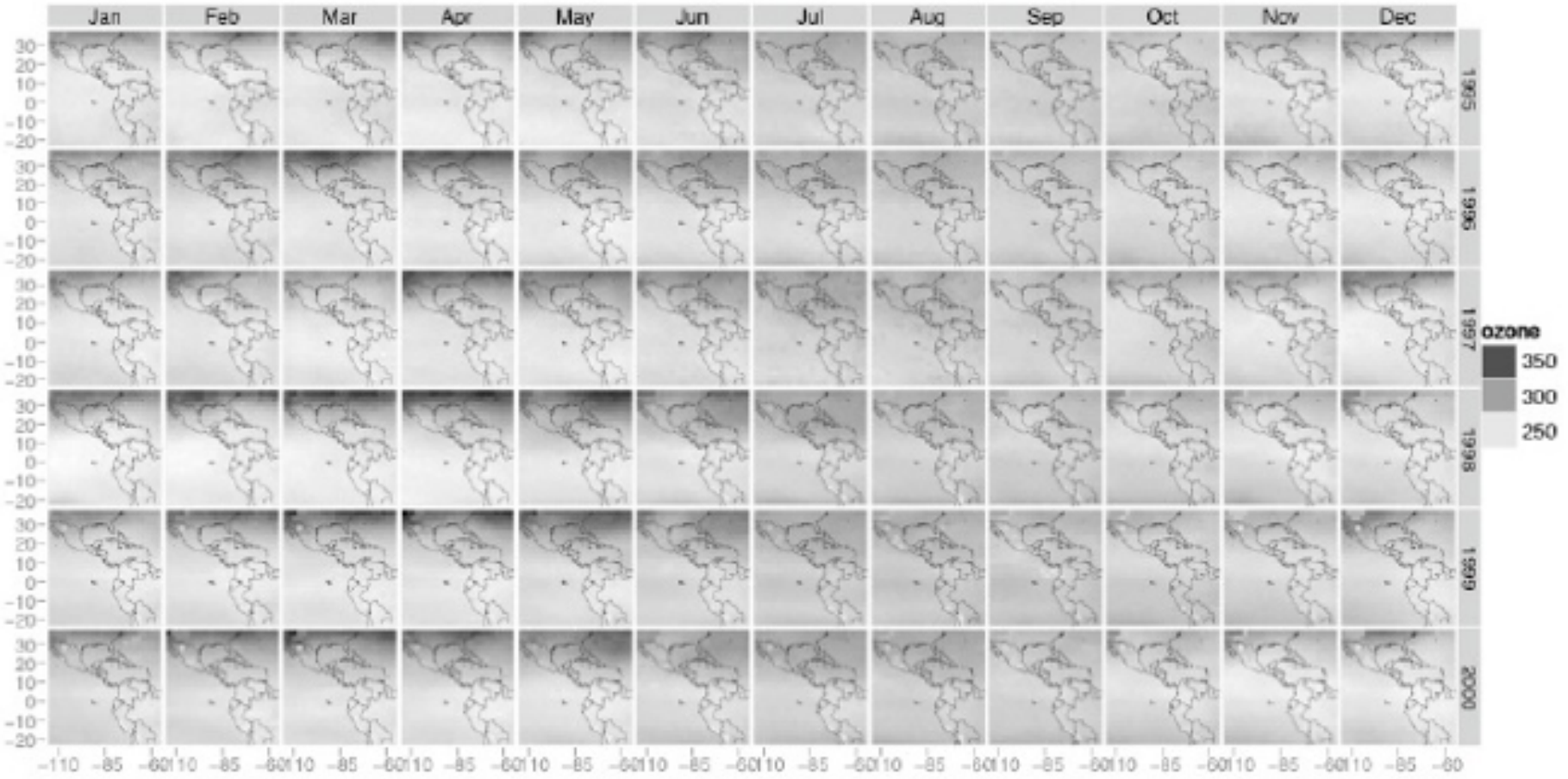

Statistics and Computing
Leland Wilkinson
The Grammar of Graphics
Second Edition
Springer

Grammar of Graphics [Wilkinson, Wickham]

Data	Input data to visualize
Operators	Grouping, statistics, layout
Coordinates	Cartesian & polar coordinates
Scales	Map data values to visual values
Guides	Axes & legends visualize scales
Marks	Geometric primitives




```
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 Languages

Tableau VizQL, ggplot2

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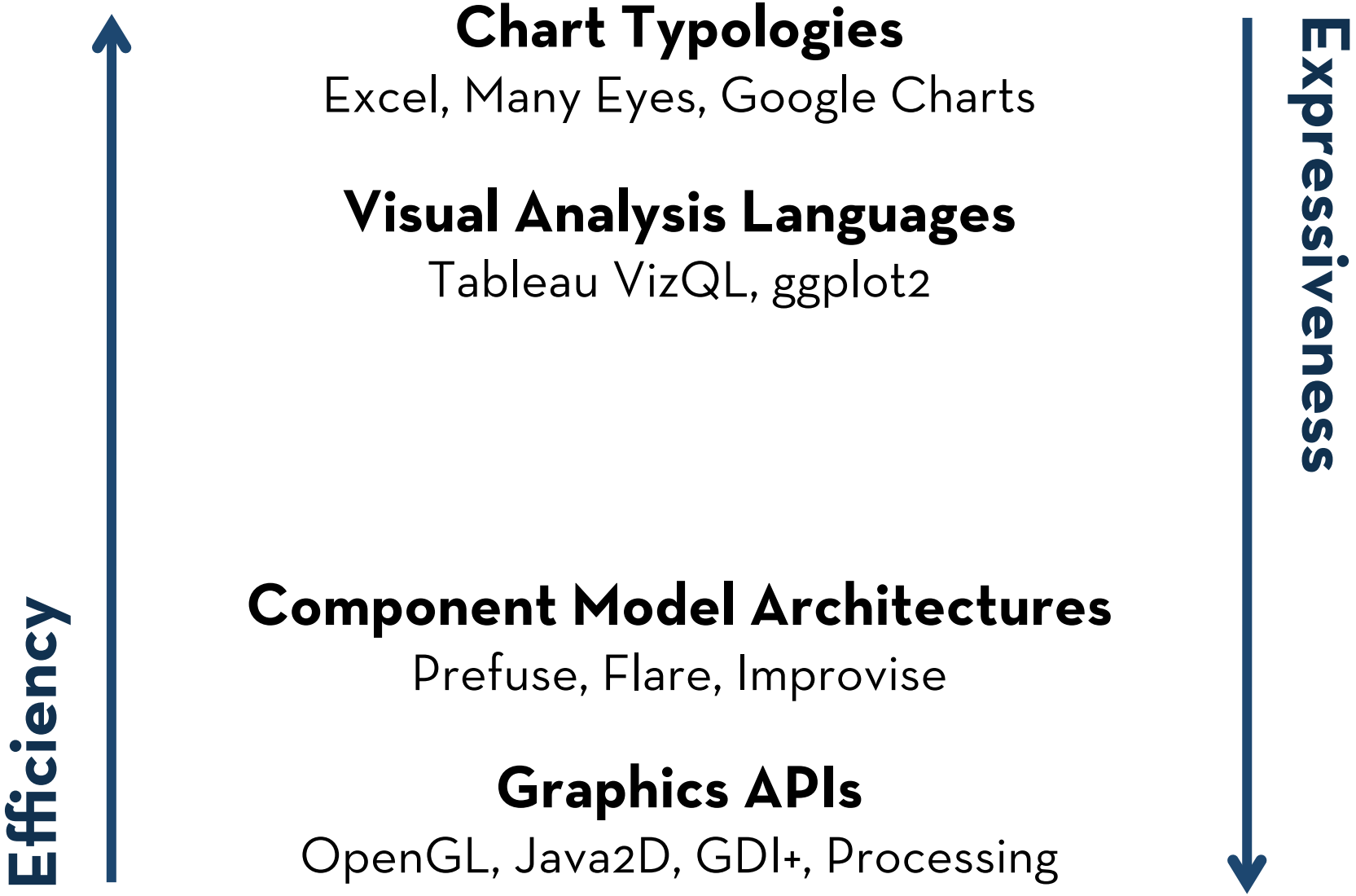
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OpenGL, Java2D, GDI+, Processing
Efficiency
Expressiveness

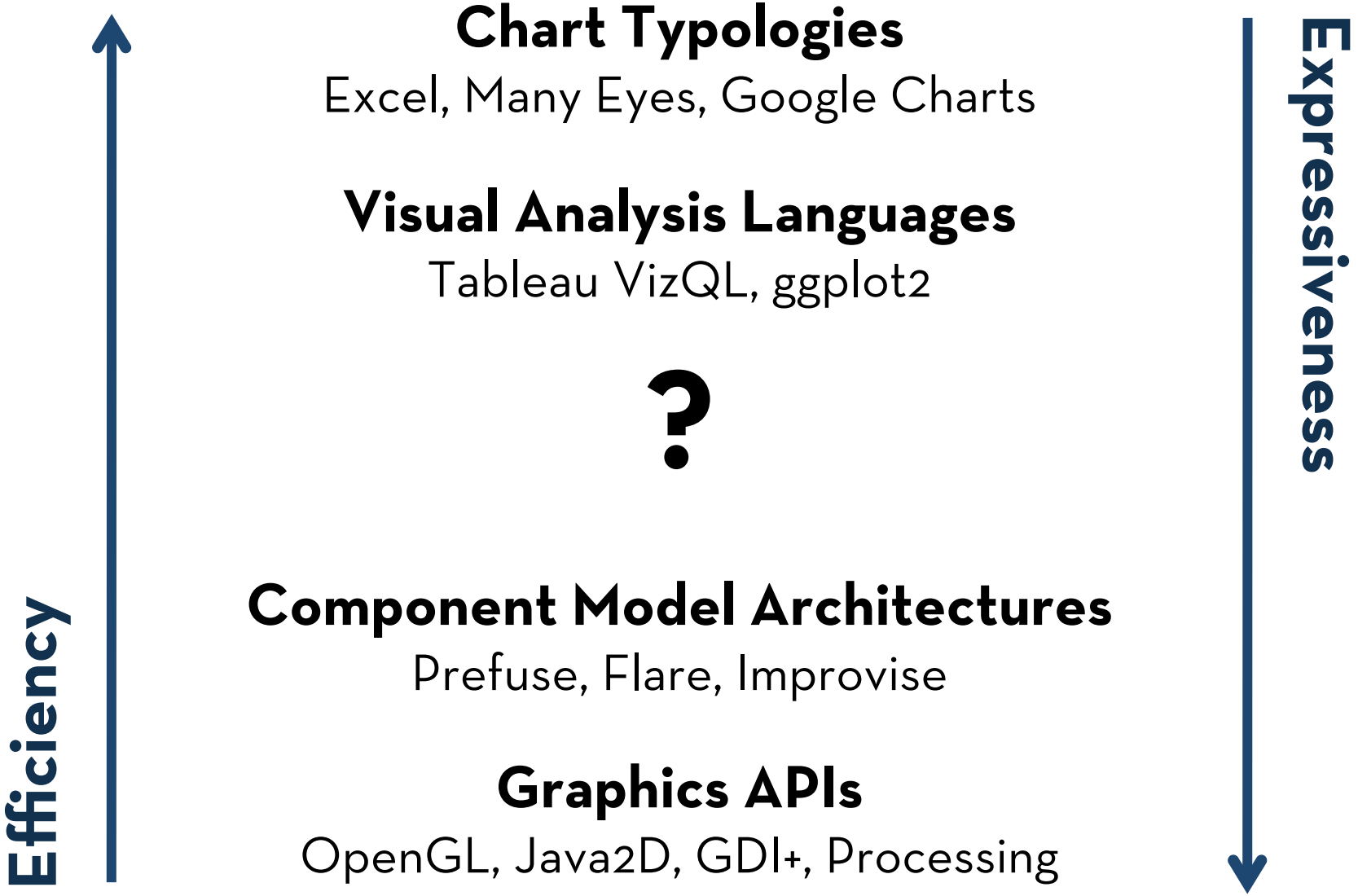
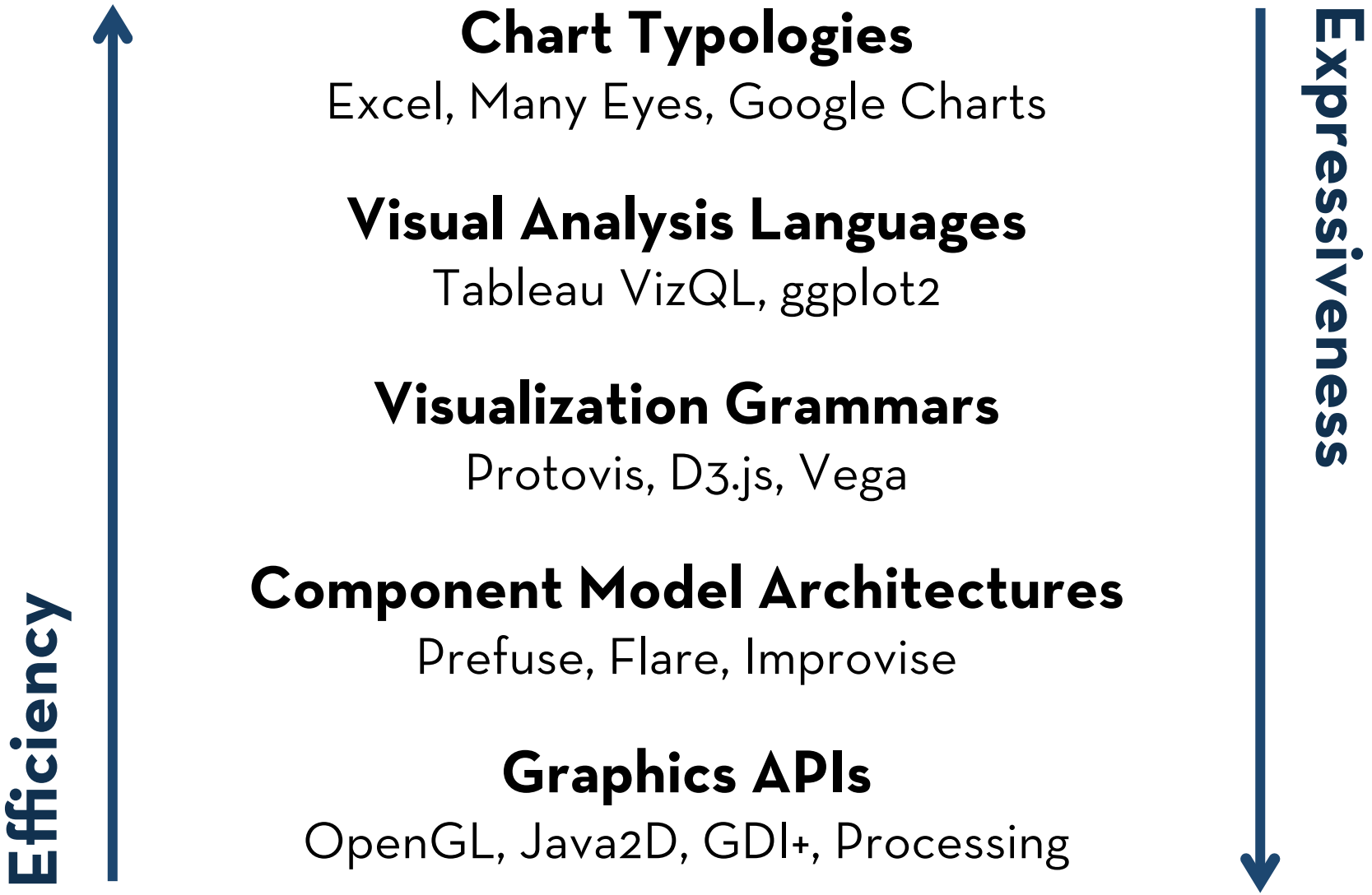


Chart Typologies
Excel, Many Eyes, Google Charts
Visual Analysis Languages
Tableau VizQL, ggplot2
?
Component Model Architectures
Prefuse, Flare, Improvise
Graphics APIs
OpenGL, Java2D, GDI+, Processing
Efficiency
Expressiveness

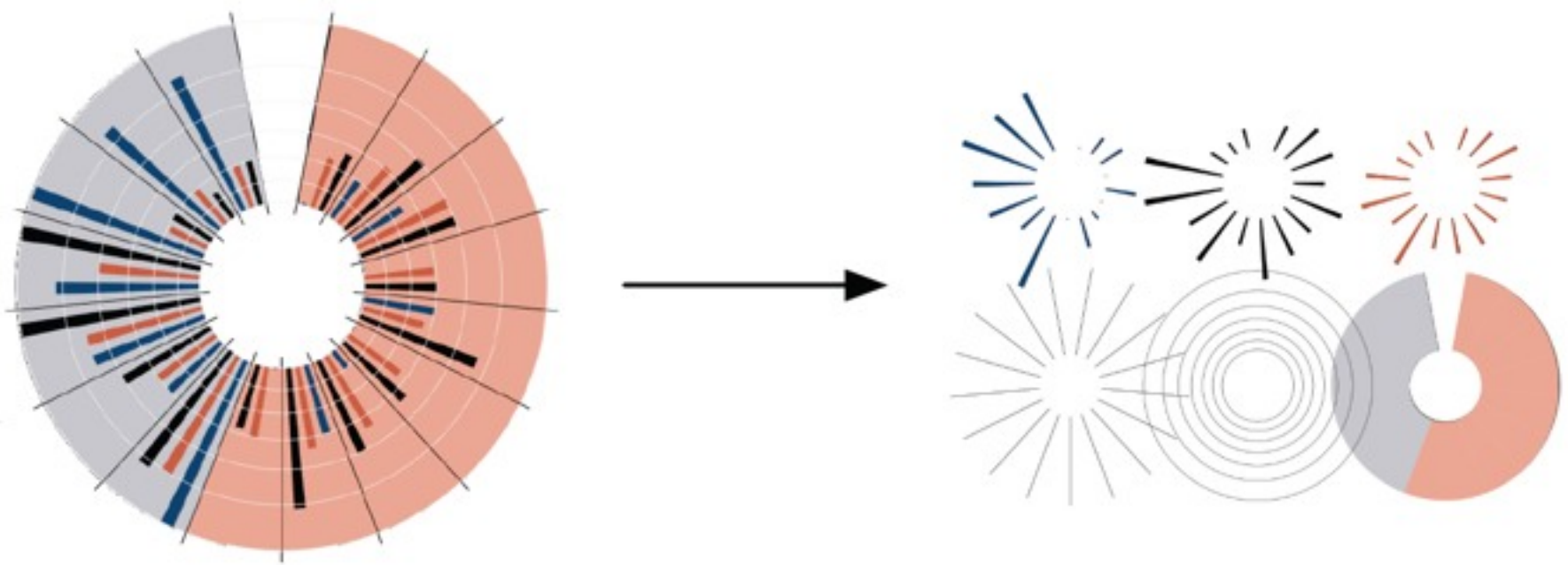

Efficiency
Chart Typologies
Excel, Many Eyes, Google Charts
Visual Analysis Languages
Tableau VizQL, ggplot2
Visualization Grammars
Protovis, D3.js, Vega
Component Model Architectures
Prefuse, Flare, Improvise
Graphics APIs
OpenGL, Java2D, GDI+, Processing
Expressiveness

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**.

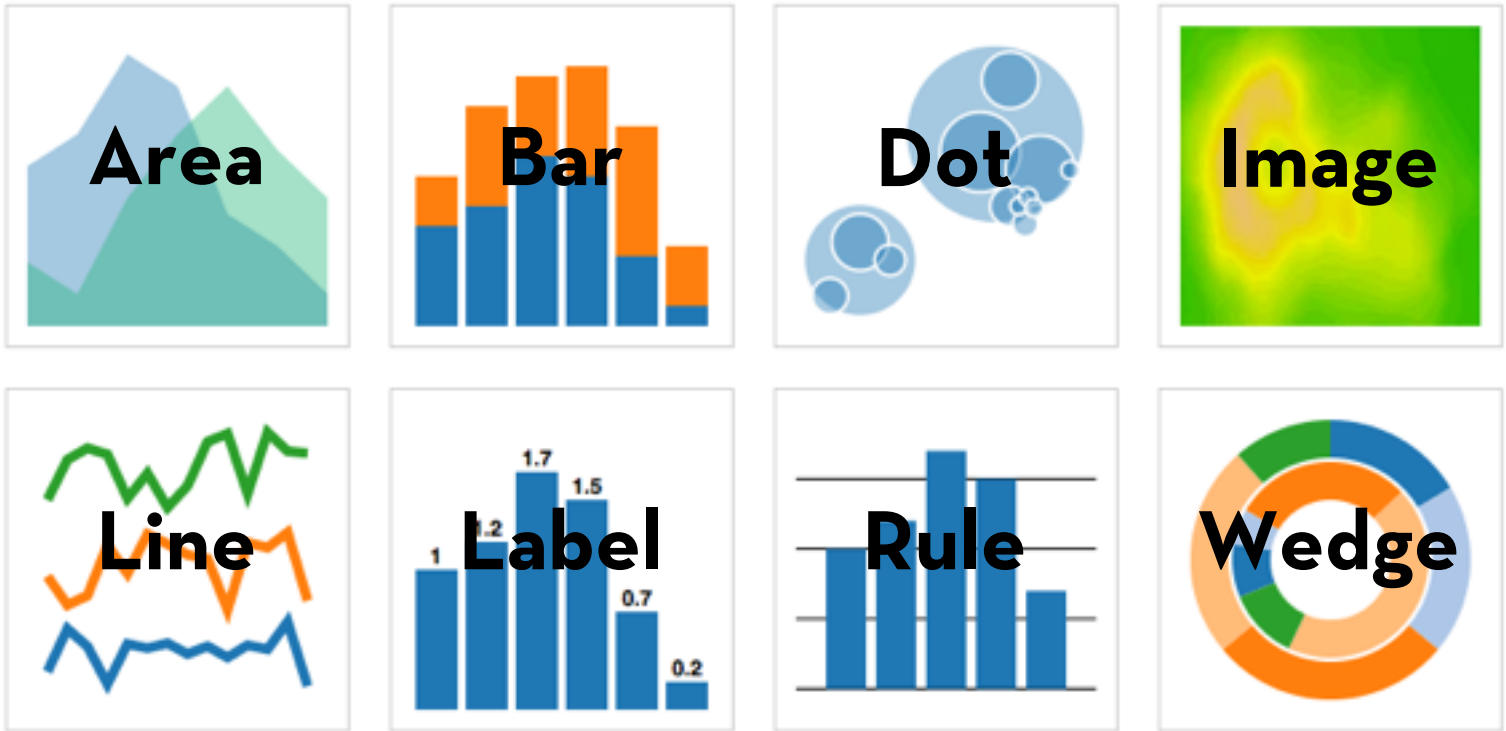
J. W. Tukey, *The Future of Data Analysis*, 1962.

Protovis: A Language for Visualization



A graphic is a composition of data-representative marks.

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



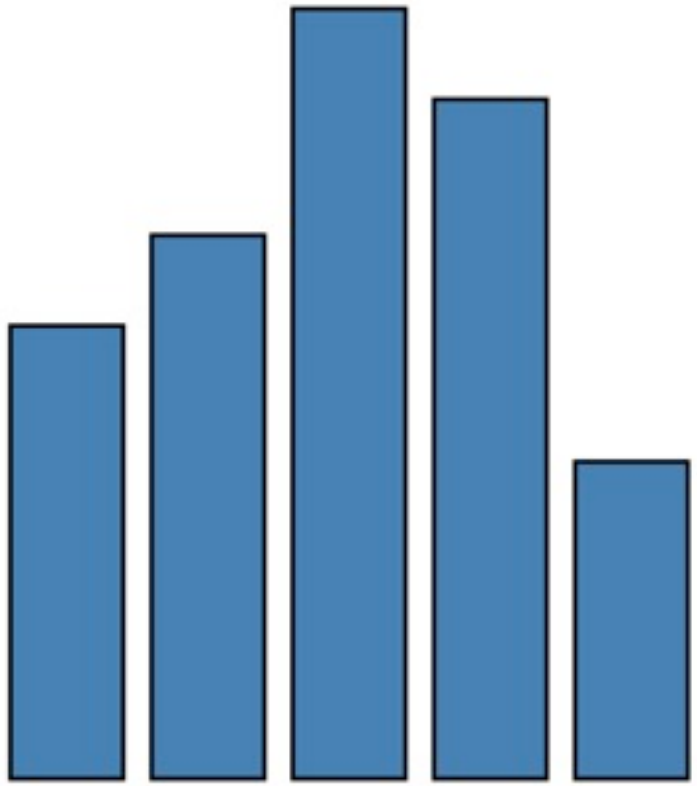
MARKS: Protovis graphical primitives

MARK $\lambda: D \rightarrow R$

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

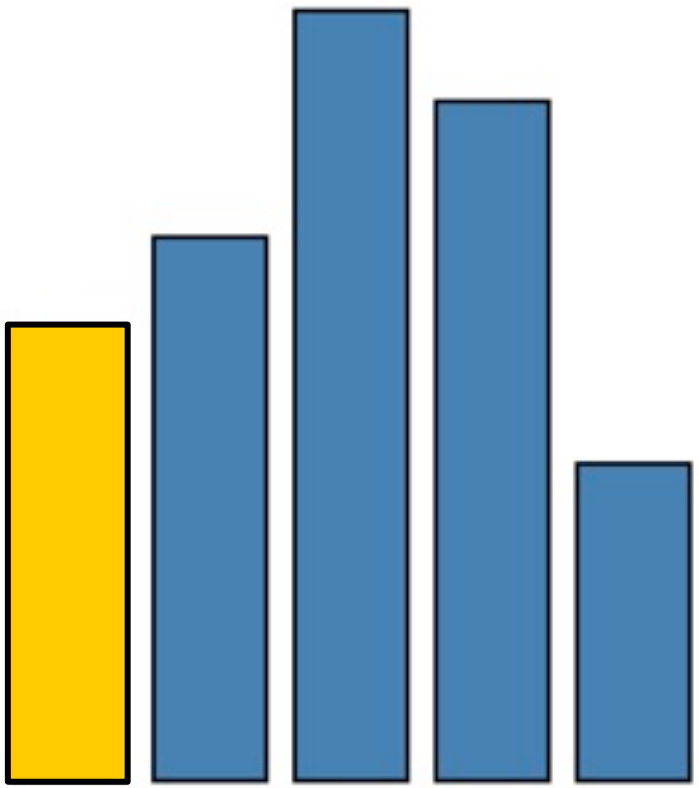
BAR $\lambda: D \rightarrow R$

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				
...	...				



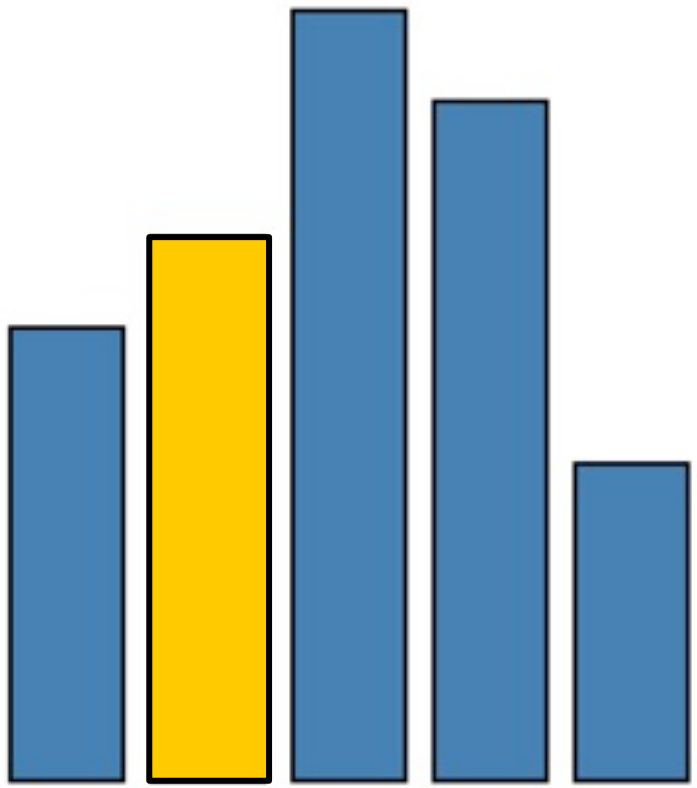
BAR $\lambda: D \rightarrow R$

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				
...	...				



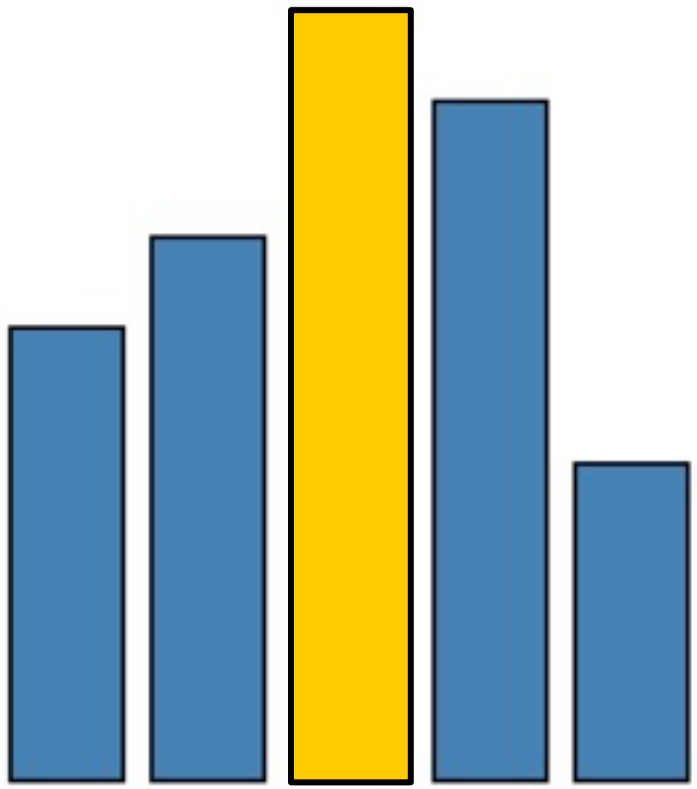
BAR $\lambda: D \rightarrow R$

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				
...	...				



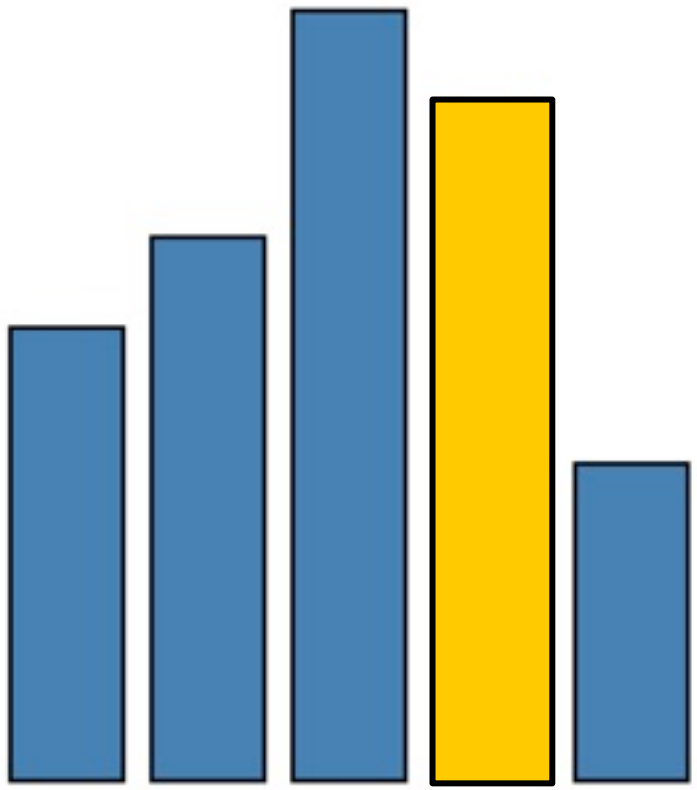
BAR $\lambda: D \rightarrow R$

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				
...	...				



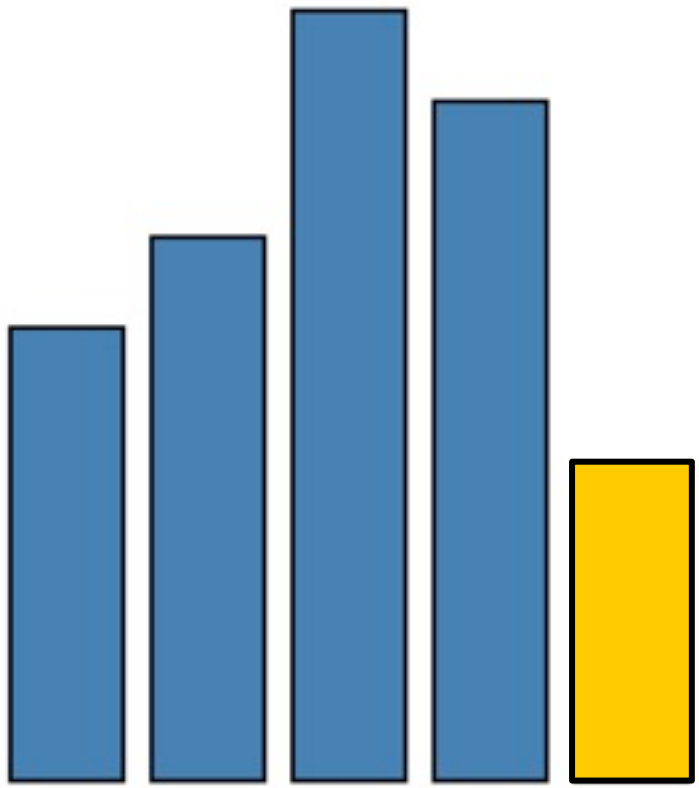
BAR $\lambda: D \rightarrow R$

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				
...	...				



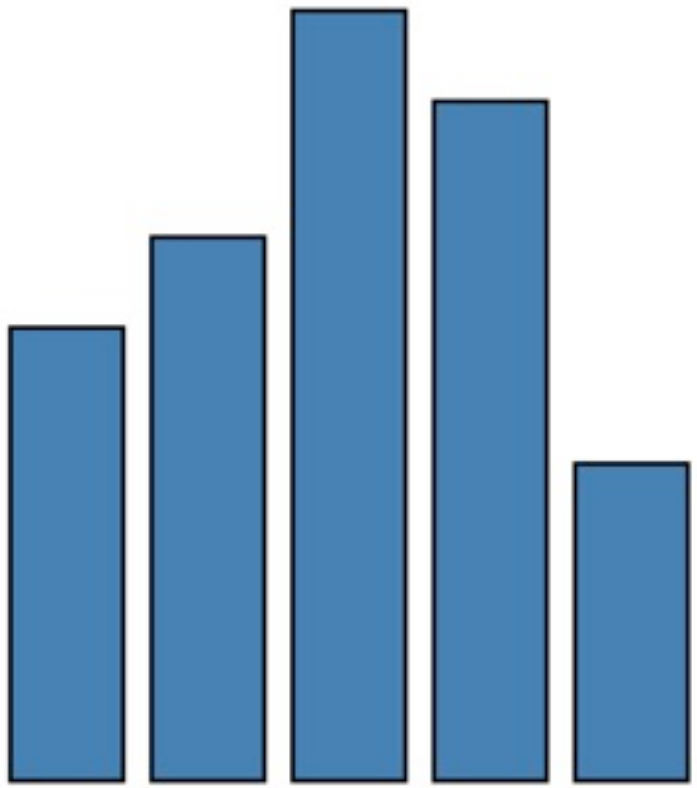
BAR $\lambda: D \rightarrow R$

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				
...	...				

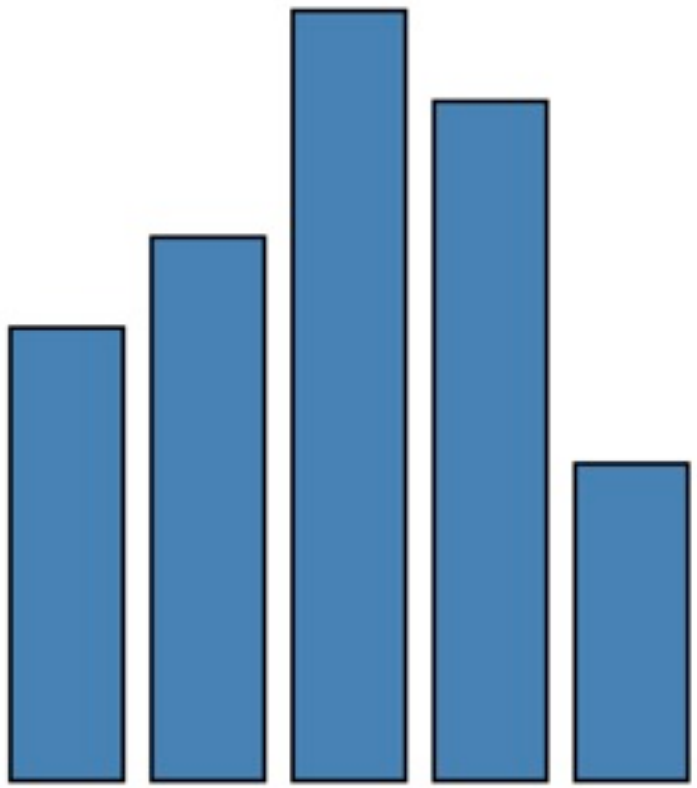


BAR $\lambda: D \rightarrow R$

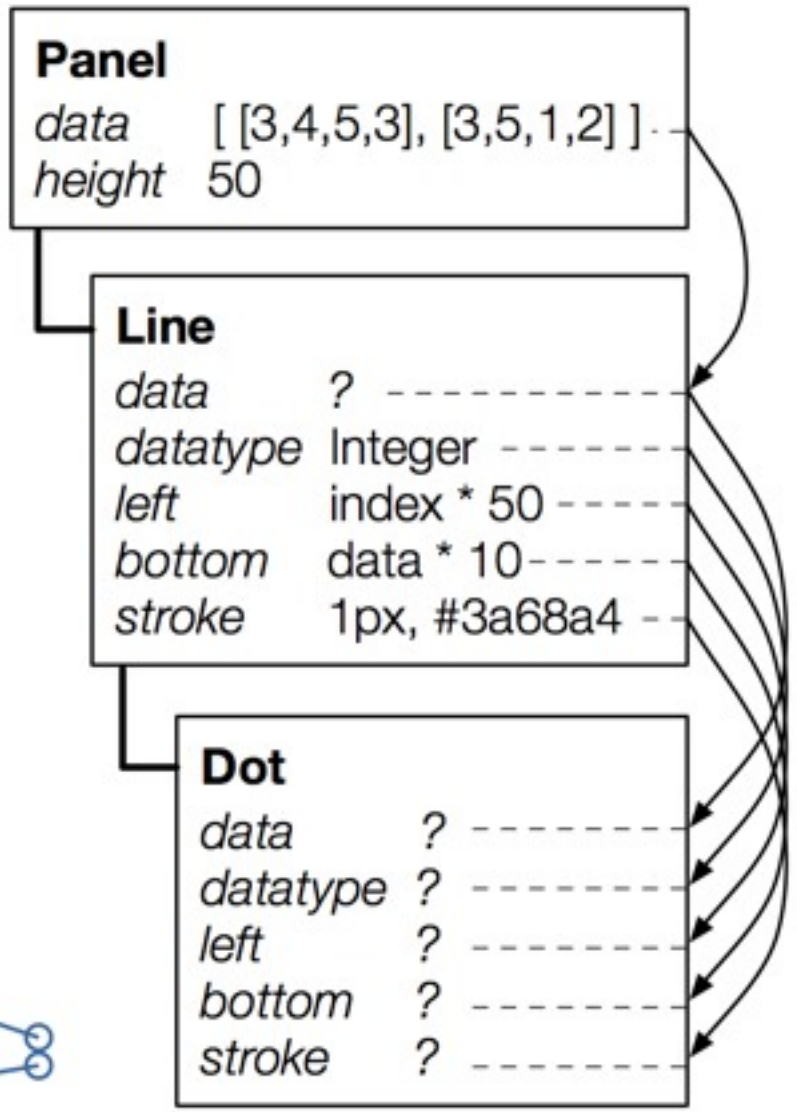
data	1	1.2	1.7	1.5	0.7
visible	true				
left	λ: index * 25				
bottom	0				
width	20				
height	λ: datum * 80				
fillStyle	blue				
strokeStyle	black				
lineWidth	1.5				
...	...				

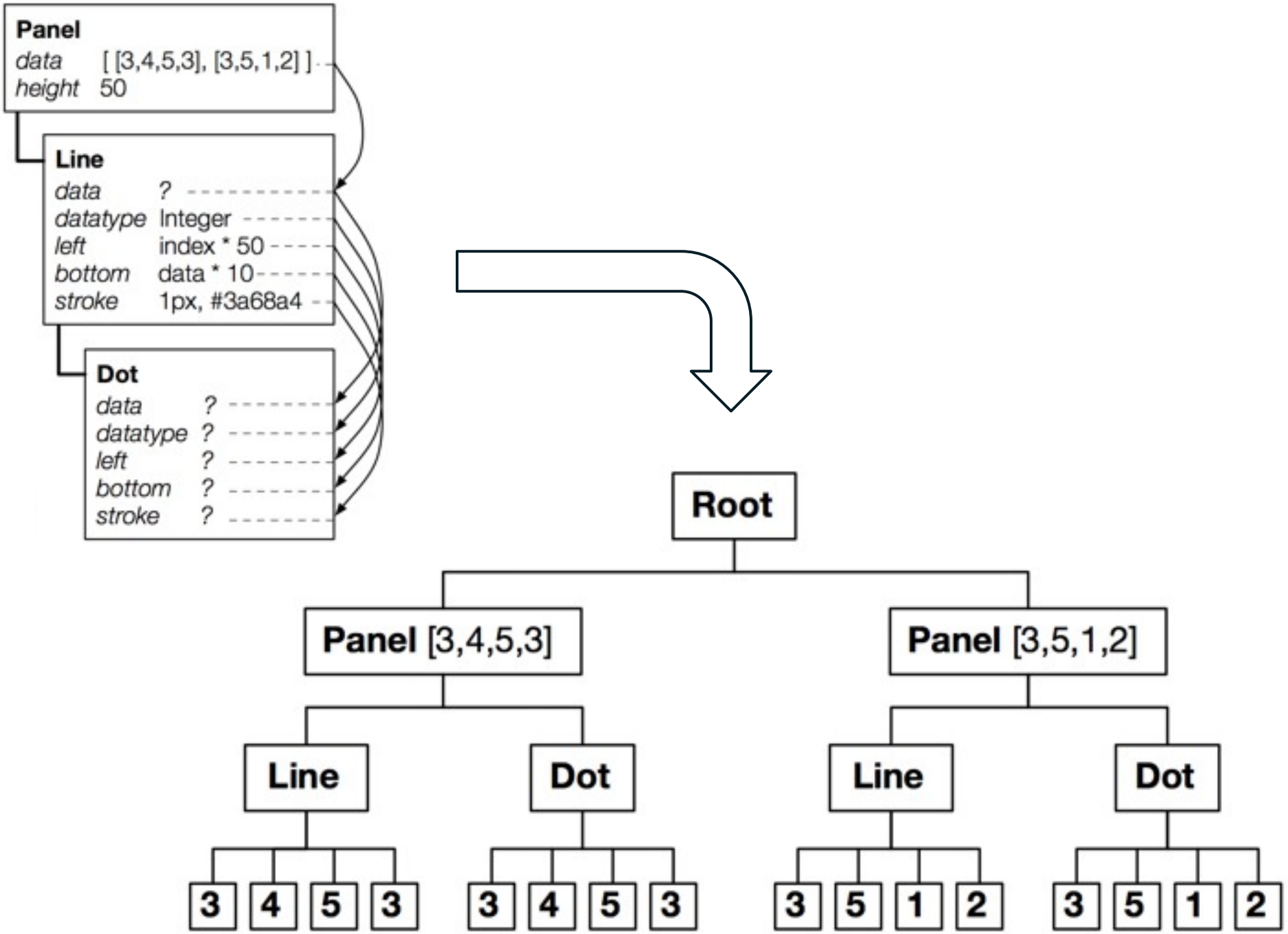


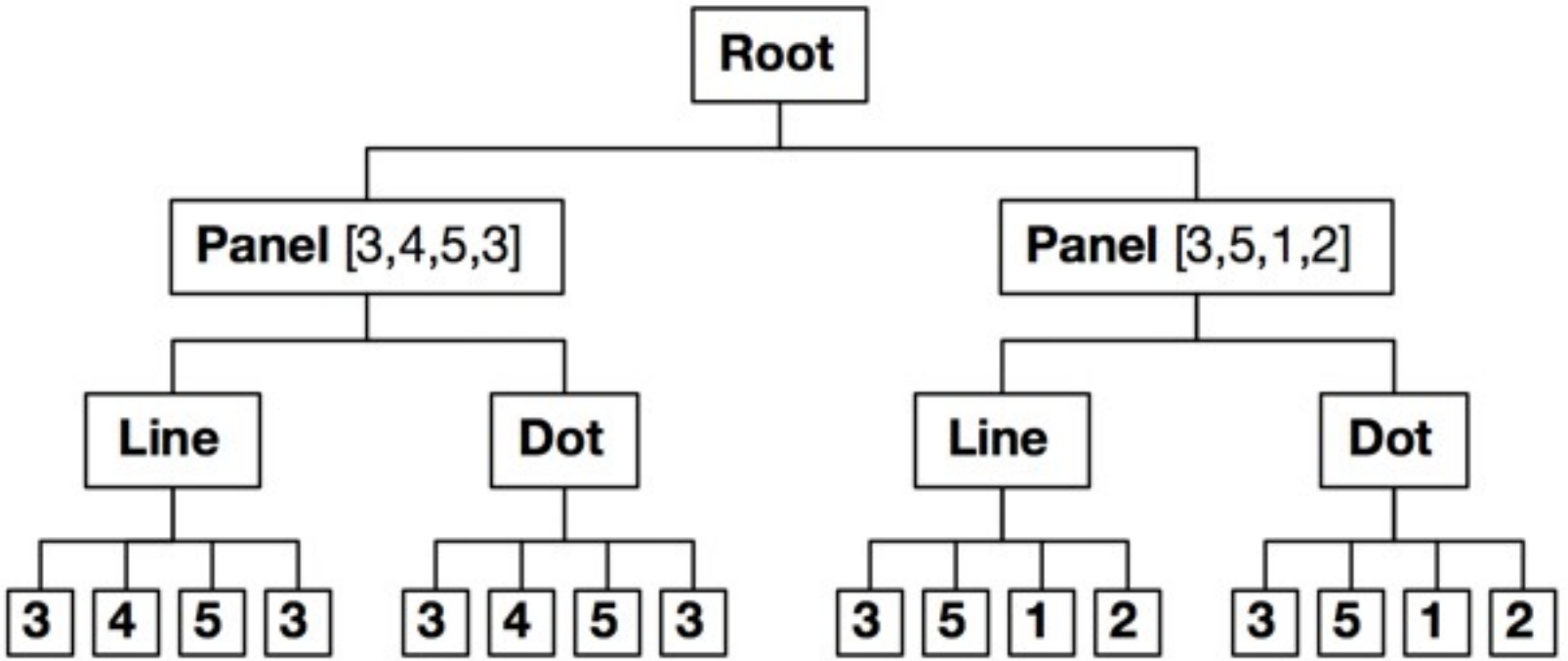
```
var vis = new pv.Panel();

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();
```

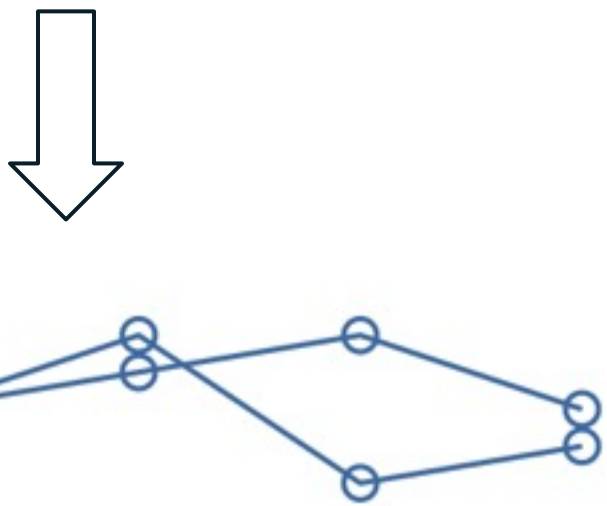


```
var data = [[3,4,5,3], [3,5,1,2]];

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





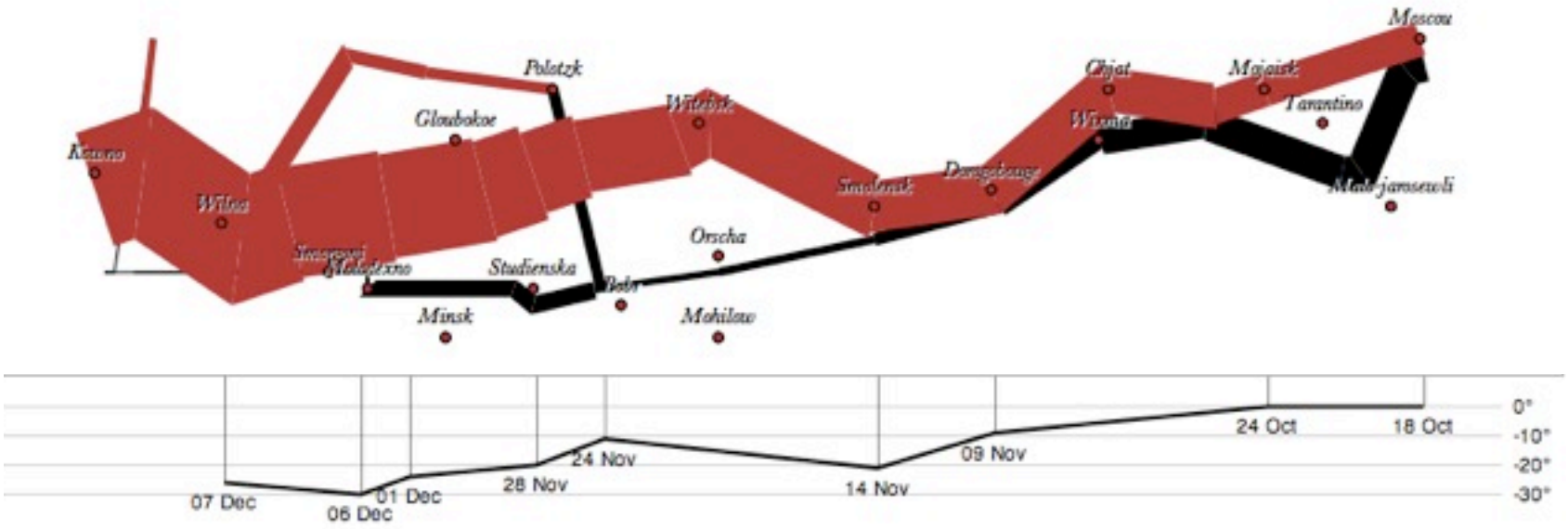
Event Handling
DOM -> Protovis

.on("mousemove",
function(d,i) {...})

Productivity - *Faster Design Cycle, Less Code*
Comparison: 5x less code, 10x less dev time

Portability - *Multiple Implementations*
JavaScript, Adobe Flash, Java/JVM

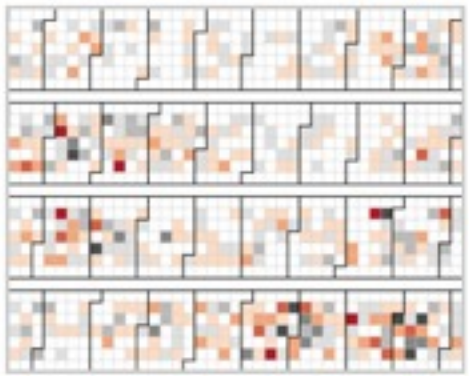
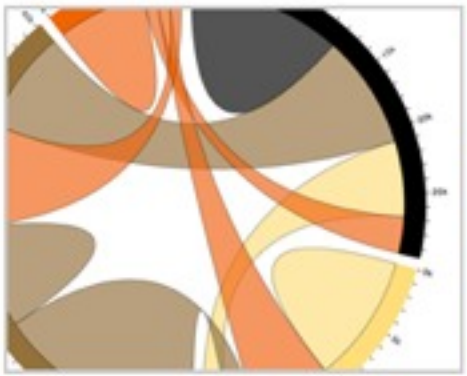
Performance - *Optimization* (in Protovis-Java)
Just-in-time compilation; parallel execution
Hardware accelerated rendering
Up to **20x scalability boost** over prior toolkits

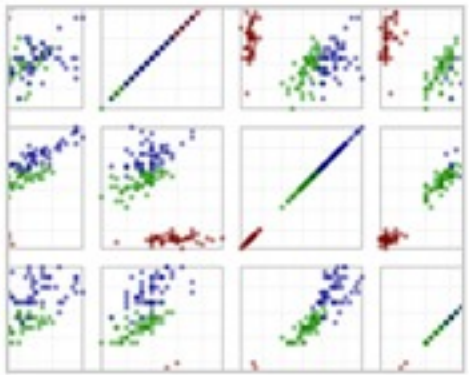
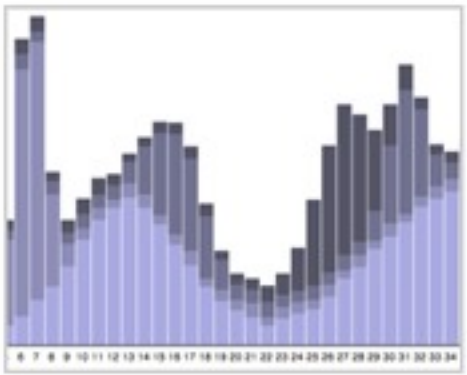
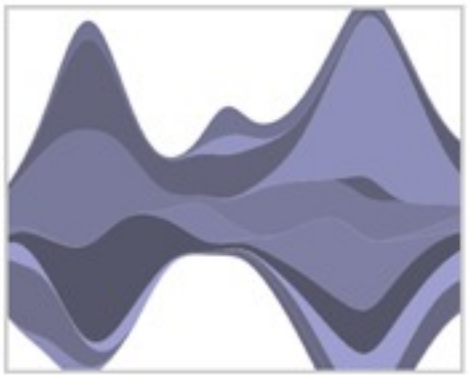
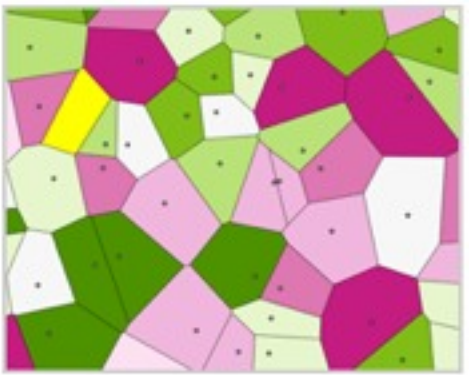



```
var army = pv.nest(napoleon.army, "dir", "group“);
var vis = new pv.Panel();

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");
```

d3.js Data-Driven Documents

with Mike Bostock & Vadim Ogievetsky

Protovis

Specialized mark types

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

Specify a scene (nouns)

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

Protovis

Specialized mark types

+ Streamlined design
- Limits expressiveness
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- Harder to debug
- Self-contained model

Specify a scene (nouns)

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

D3

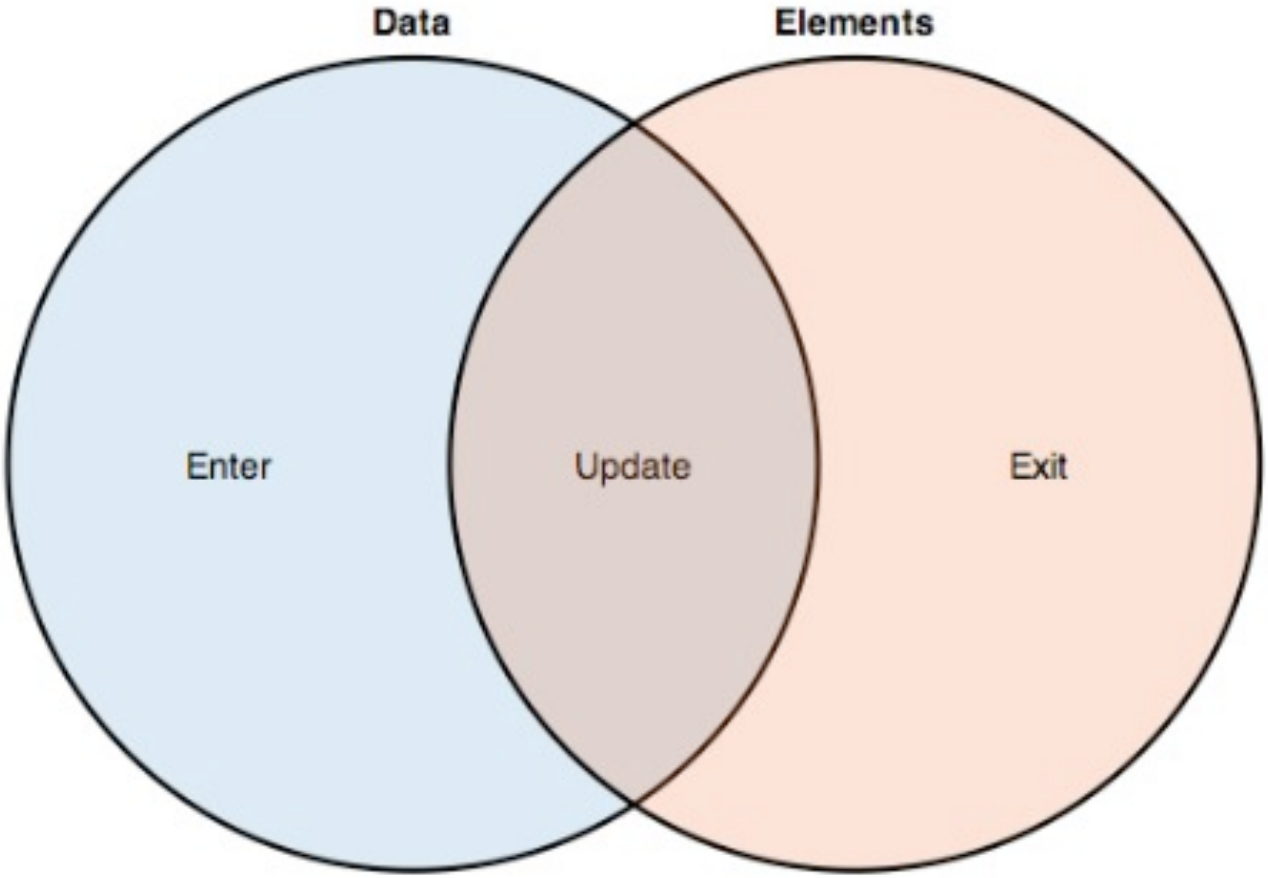
Bind data to DOM

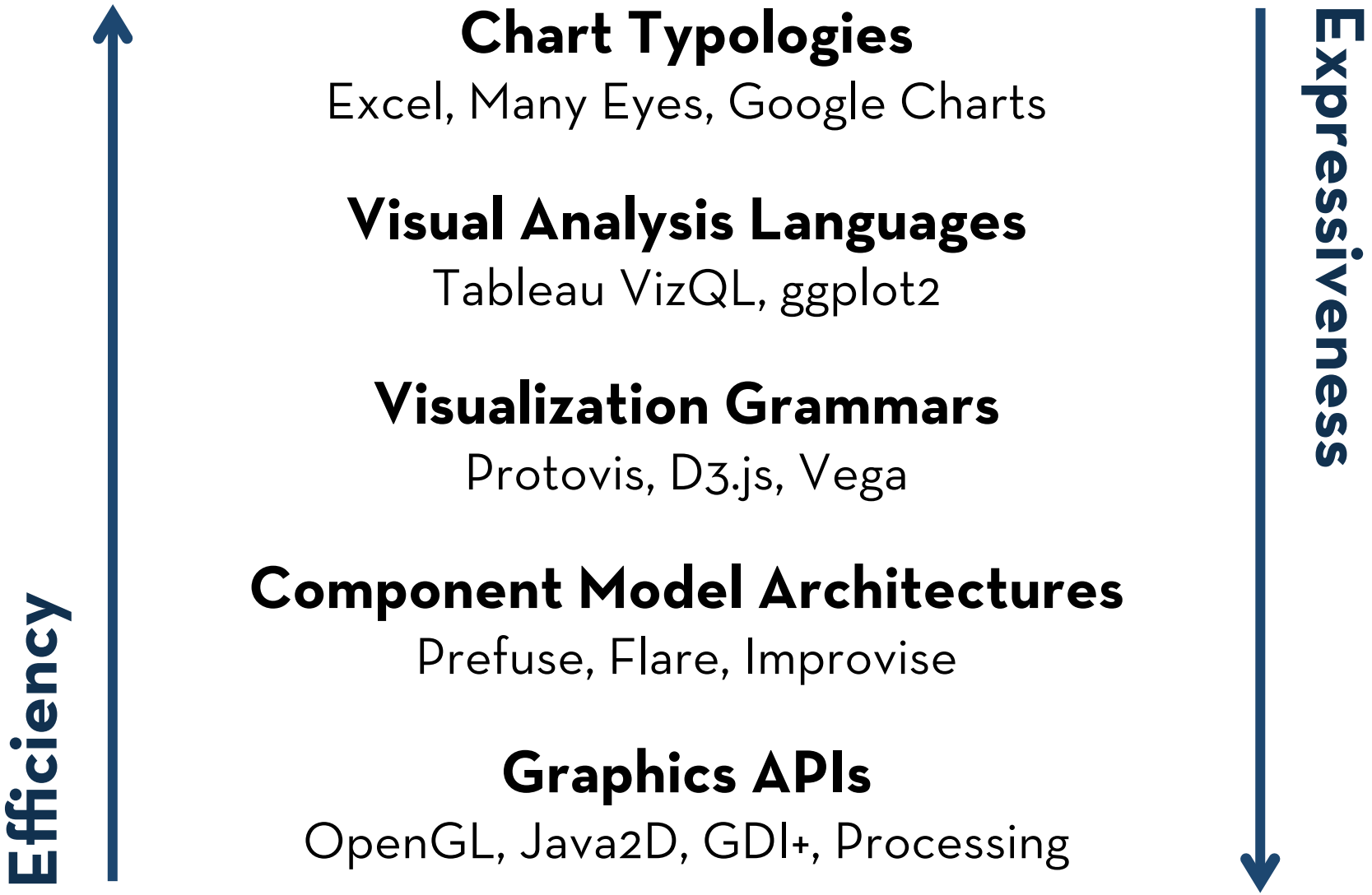
- Exposes SVG/CSS/…
+ Exposes SVG/CSS/…
+ Less overhead (faster)
+ Debug in browser
+ Use with other tools

Transform a scene (verbs)

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

Selection + Data Join




Efficiency
Chart Typologies
Excel, Many Eyes, Google Charts
Visual Analysis Languages
Tableau VizQL, ggplot2
Visualization Grammars
Protovis, D3.js, Vega
Component Model Architectures
Prefuse, Flare, Improvise
Graphics APIs
OpenGL, Java2D, GDI+, Processing
Expressiveness

Administrivia

Assignment 2: Exploratory Data Analysis

Use visualization software to form & answer questions

First steps:

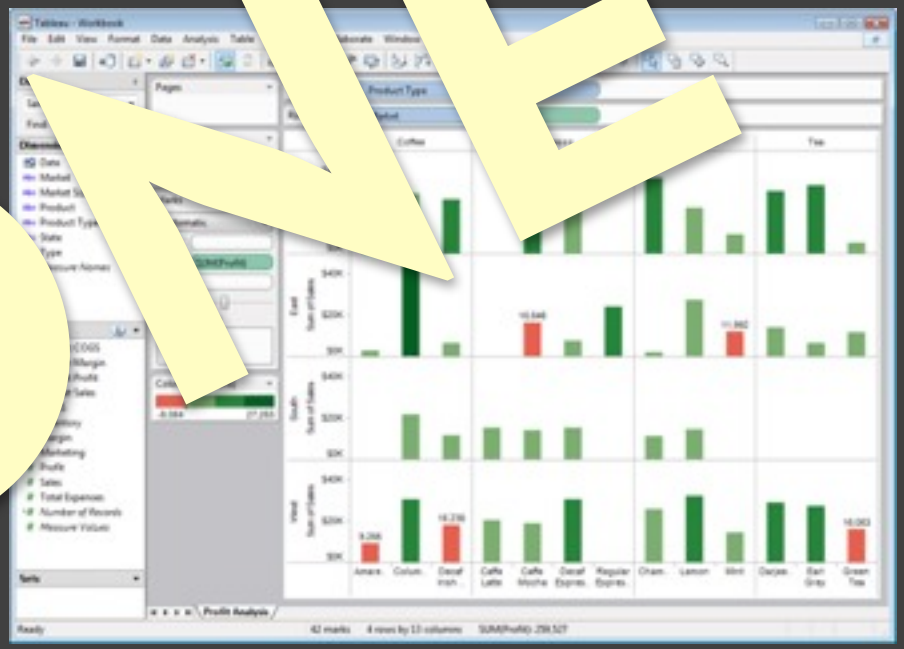
- Step 1: Pick domain & data
- Step 2: Pose questions
- Step 3: Profile the data
- Iterate as needed

Create visualizations

- Integrate with data
- Refine your questions

Make w notebook

- Keep record of your analysis
- Prepare a final graphic and caption



DONE

Due by 5:00pm
Monday, Jan 27

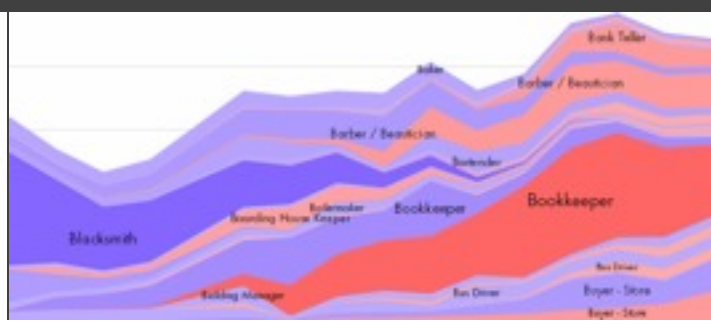
A3: Interactive Visualization

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

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

You should work in groups of 2.

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

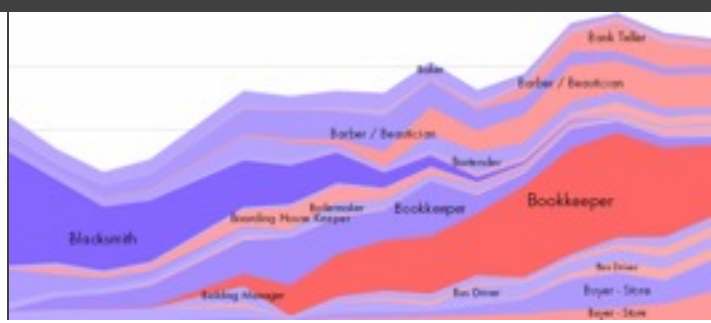


Assignment 3: Project Partners

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

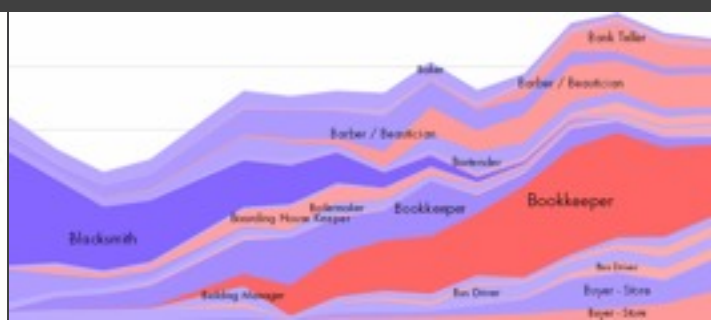
If you do not have a partner, you should

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



Assignment 3 Tips

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



Comparing Approaches

No Humble Pie

Pie Chart: Processing

```
size(150, 150); background(255);
smooth(); noStroke();
int diameter = 140;
float[] data = {1, 1.2, 1.7, 1.5, .7};
float lastAng = 0, sum = 0;
for (int i = 0; i < data.length; i++)
  sum += data[i];
for (int i = 0; i < data.length; i++) {
  fill(data[i] * 120);
  float ang = data[i] / sum * 2 * PI;
  arc(width / 2, height / 2, diameter, diameter,
      lastAng, lastAng + ang);
  lastAng += ang;
}
```

Pie Chart: Flare

```
var data:Data = Data.fromArray(
   [{value:1}, {value:1.2}, {value:1.7}, ...]
);
var vis:Visualization = new Visualization(data);

vis.bounds = new Rectangle(0, 0, 150, 150);
vis.operators.add(new PieLayout("data.value", 0.9));
vis.operators.add(new ColorEncoder(
    "data.value", "nodes", "fillColor"));

vis.update();
addChild(vis);
```

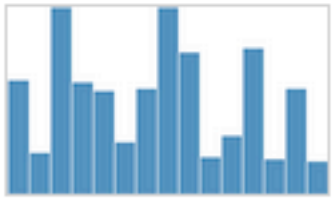
Pie Chart: Protovis

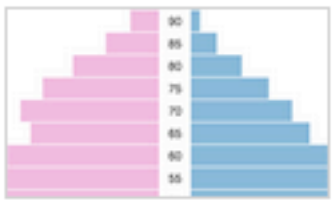
```
var vis = new pv.Panel()
    .width(150)
    .height(150)
.add(pv.Wedge)
    .left(75)
    .bottom(75)
    .outerRadius(70)
    .angle(function(d) { return d * 2 * Math.PI; })
    .data(pv.normalize([1, 1.2, 1.7, 1.5, .7]));

vis.render();
```

Pie Chart: D3

```
var data = [1, 1.2, 1.7, 1.5, .7];
var color = d3.scale.category20();
var svg = d3.select("body").append("svg")
  .attr("width", 150)
  .attr("height", 150);
var g = svg.append("g")
  .attr("transform", "translate(75, 75)");
var arcs = g.selectAll("path")
   .data(d3.layout.pie().sort(null)(data))
 .enter().append("path")
   .style("fill", function(d,i) { return color(i); })
   .attr("d", d3.svg.arc().innerRadius(0).outerRadius(70));
```

Vega & Lyra





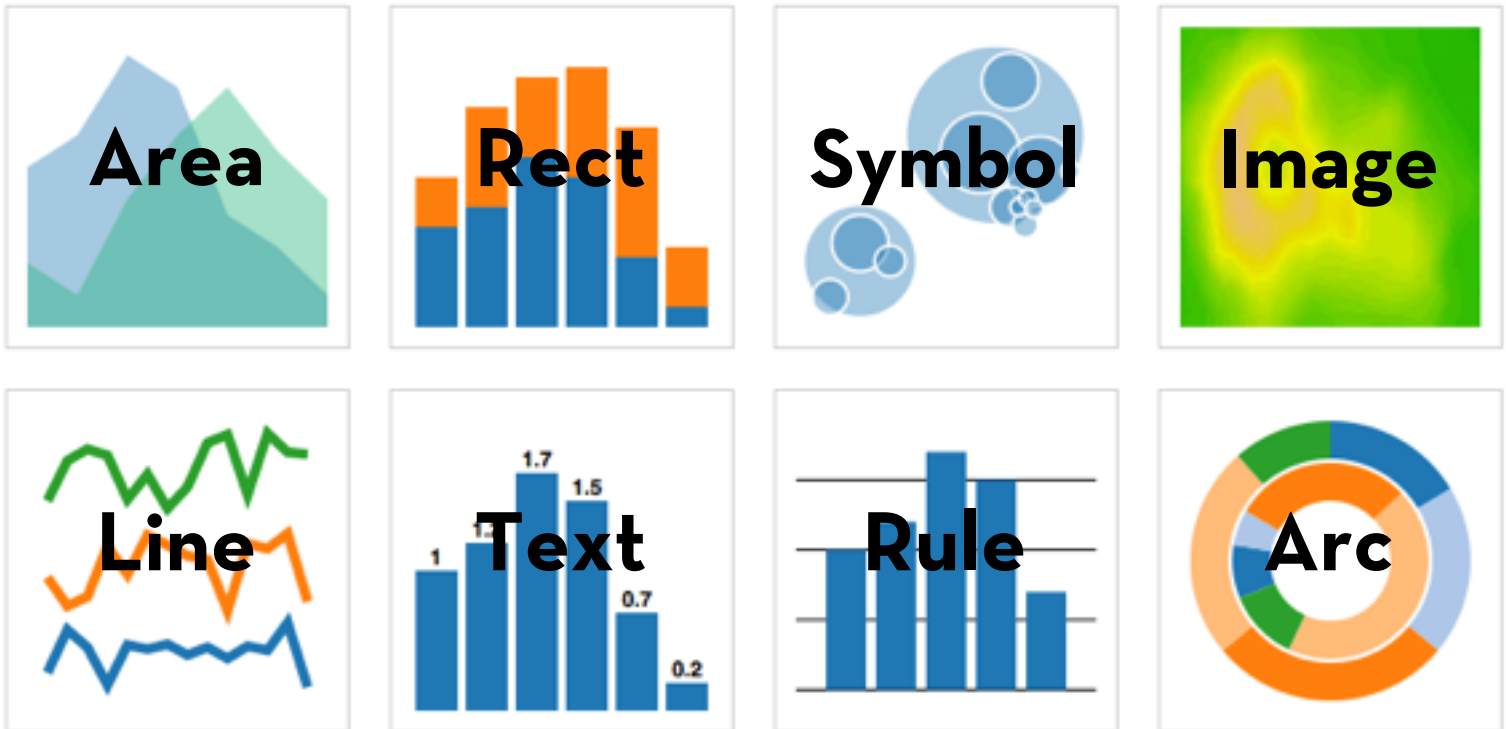
vega

vega.js (127k)
vega.min.js (63k)
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.

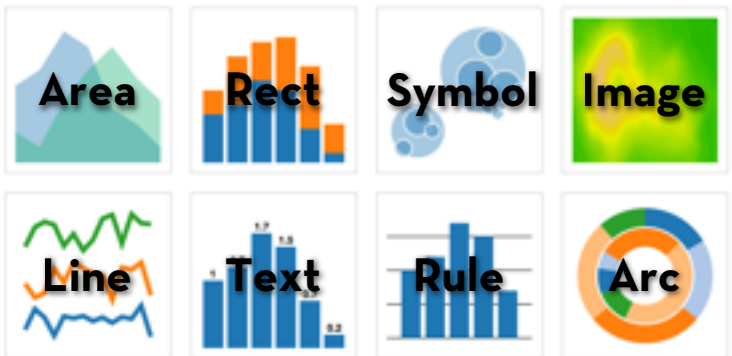
Read the tutorial, browse the documentation, and then explore Vega visualizations using the web-based Vega Editor.



MARKS: Vega graphical primitives

Vega 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



```
{
  "name": "pie", "width": 150, "height": 150,
  "data": [{
    "name": "table",
    "values": [1, 1.2, 1.7, 1.5, 0.7],
    "transform": [{"type": "pie", "value": "data"}]
  }],
  "scales": [
    {"name": "color", "type": "ordinal", "range": "category20"}
  ],
  "marks": [{
    "type": "arc",
    "from": {"data": "table"},
    "properties": {
      "enter": {
        "x": {"group": "width", "mult": 0.5},
        "y": {"group": "height", "mult": 0.5},
        "startAngle": {"field": "startAngle"},
        "endAngle": {"field": "endAngle"},
        "innerRadius": {"value": 0},
        "outerRadius": {"value": 70},
        "fill": {"scale": "color", "field": "index"}
      }
    }
  }]
}
```

Vega Design Goals

Balancing rapid + expressive design

Protovis-style marks, data transforms & layouts

Reuse & sharing of visualization designs

JSON format -> chart components or stand-alone vis

Support programmatic generation

Provides an intermediate specification language

Performance & platform flexibility

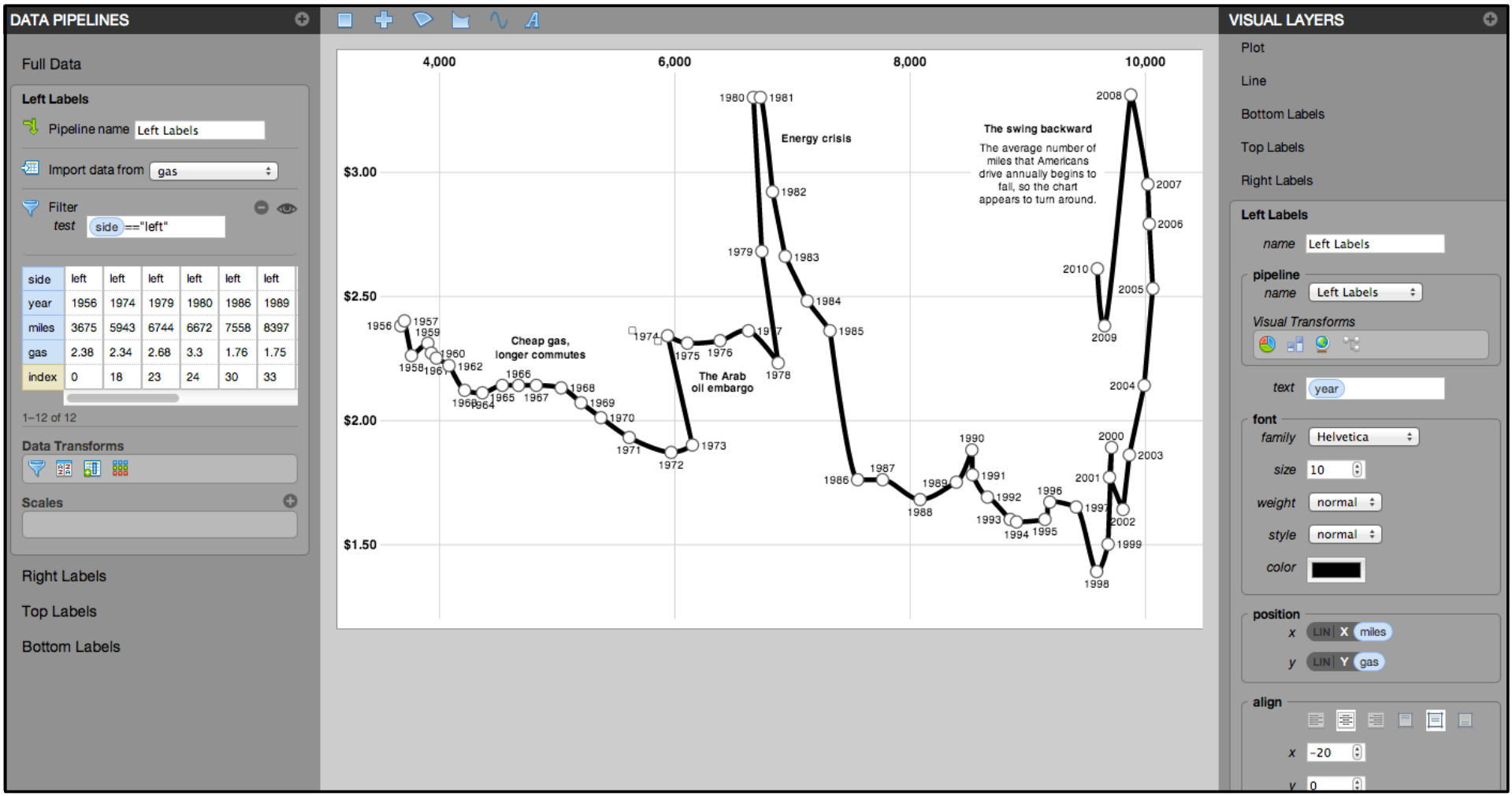
Browser or server-side; Canvas or SVG

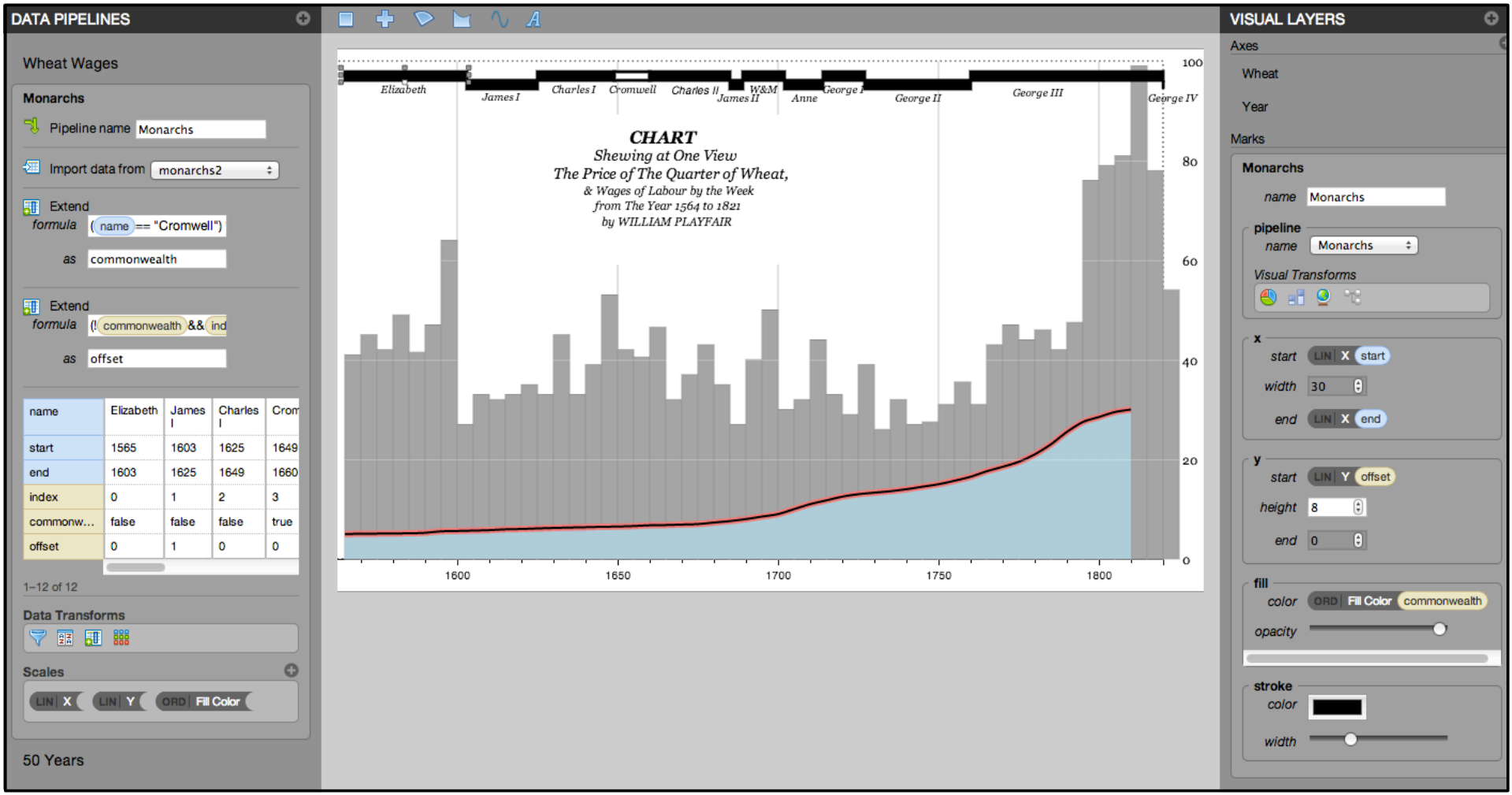
For the highest level graphics (elegant, custom, expensive), enter the crunched data or the graphical output into **Adobe Illustrator**. ...This program gives complete control over typography, line weight, color, grids, layout--just what we need for doing graphical work.

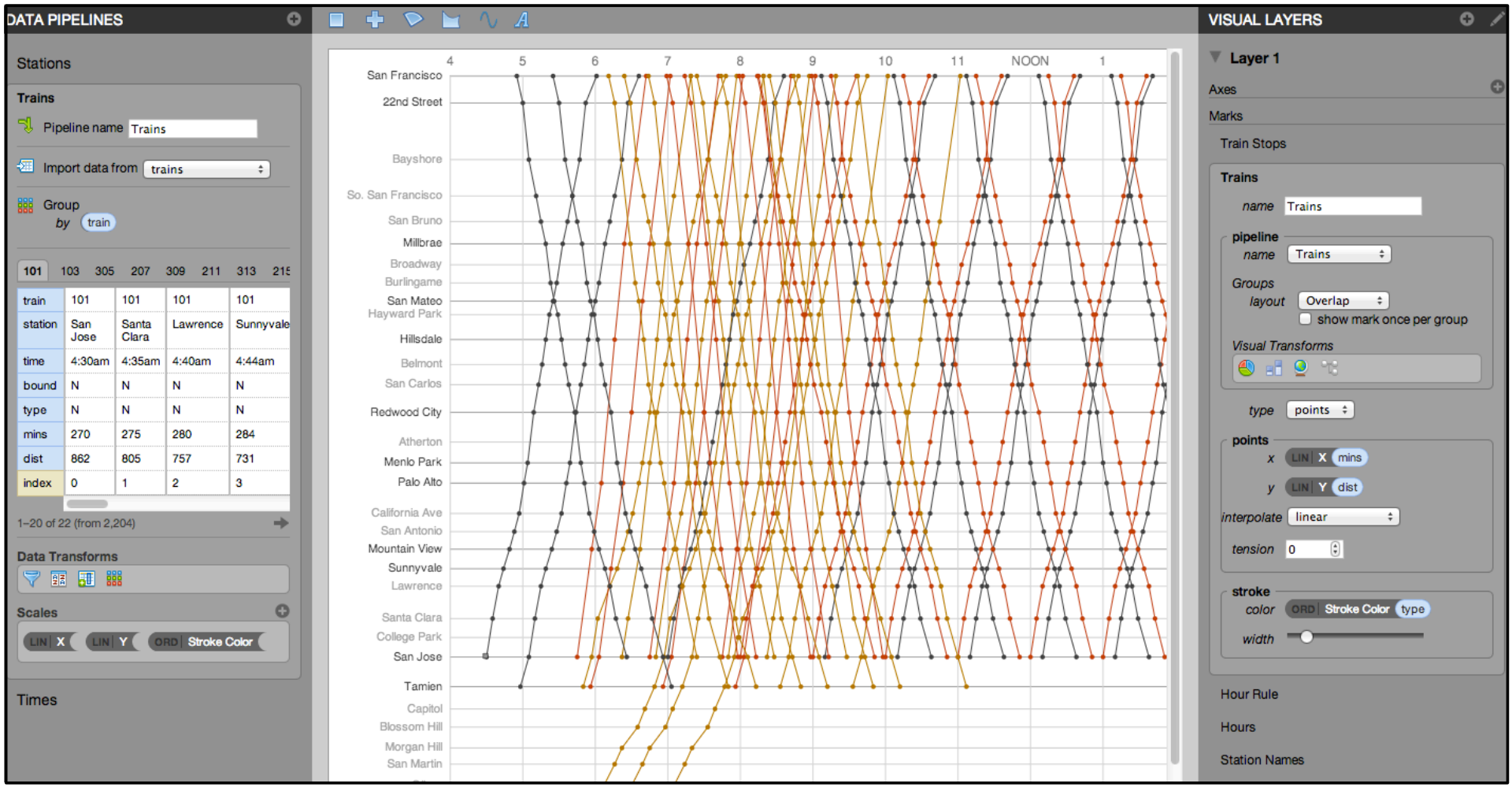
It is a serious, complex design program; you may want to work with **real graphical designers** who will surely know their way around Illustrator.

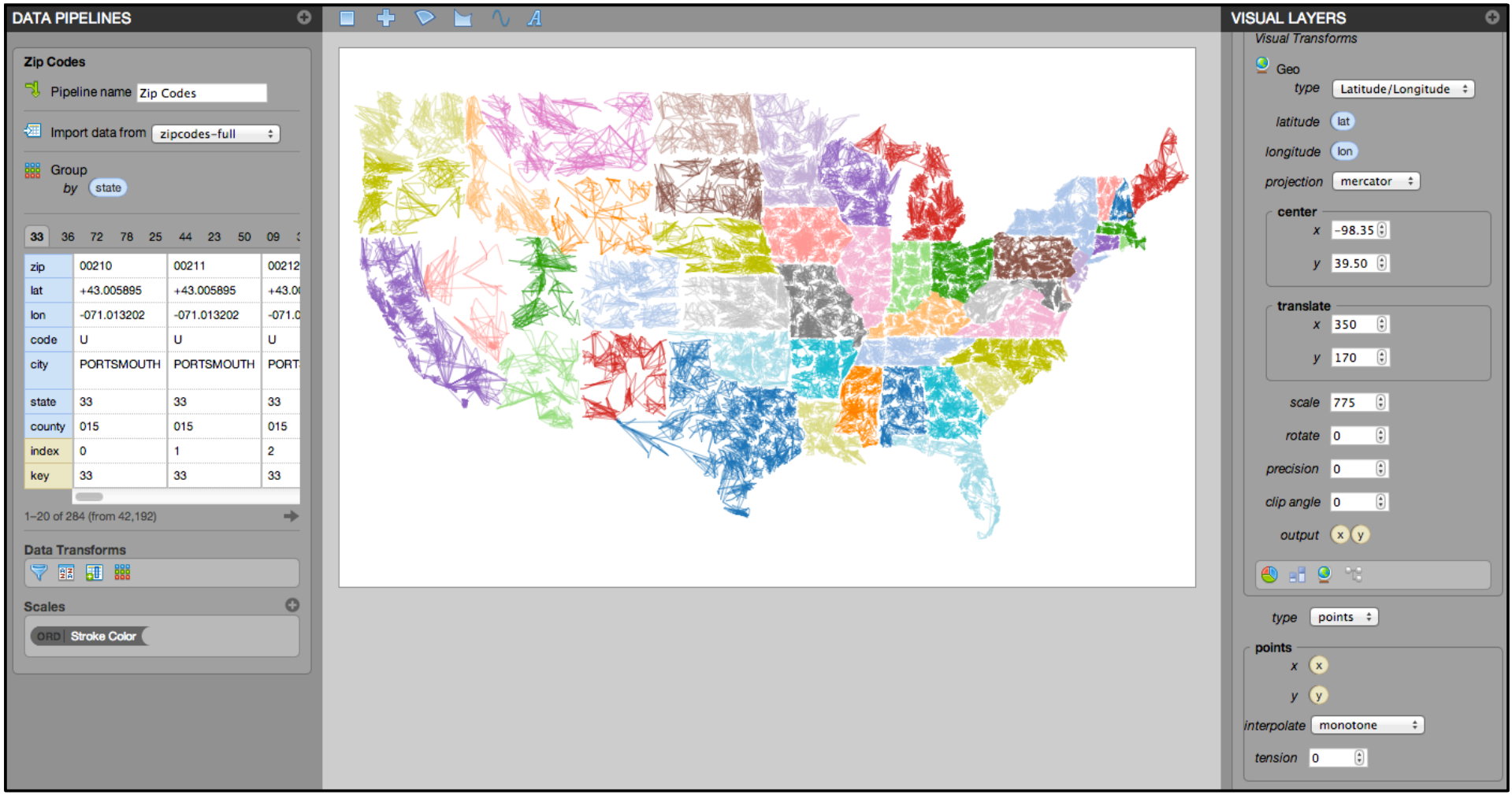
Tufte, E. *Ask E.T.: Graphics Software*, April 2001

Lyra: An Interactive Visualization Design Environment


DATA PIPELINES
Full Data
Left Labels
Pipeline name Left Labels
Import data from gas
Filter
test side=="left"
side left left left left left left
year 1956 1974 1979 1980 1986 1989
miles 3675 5943 6744 6672 7558 8397
gas 2.38 2.34 2.68 3.3 1.76 1.75
index 0 18 23 24 30 33
1–12 of 12
Data Transforms
Scales
Right Labels
Top Labels
Bottom Labels
4,000
6,000
8,000
10,000
$3.00
$2.50
$2.00
$1.50
Cheap gas, longer commutes
Energy crisis
The Arab oil embargo
The swing backward
The average number of miles that Americans drive annually begins to fall, so the chart appears to turn around.
VISUAL LAYERS
Plot
Line
Bottom Labels
Top Labels
Right Labels
Left Labels
name Left Labels
pipeline
name Left Labels
Visual Transforms
text year
font
family Helvetica
size 10
weight normal
style normal
color
position
x LIN X miles
y LIN Y gas
align
x -20
y 0


DATA PIPELINES
Wheat Wages
Monarchs
Pipeline name Monarchs
Import data from monarchs2
Extend
formula (name == "Cromwell")
as commonwealth
Extend
formula (! commonwealth && ind
as offset
name | Elizabeth | James I | Charles I | Cron
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
1–12 of 12
Data Transforms
Scales
LIN X
LIN Y
ORD Fill Color
50 Years
Elizabeth
James I
Charles I
Cromwell
Charles II
James II
W&M
Anne
George I
George II
George III
George IV
CHART
Shewing at One View
The Price of The Quarter of Wheat,
& Wages of Labour by the Week
from The Year 1564 to 1821
by WILLIAM PLAYFAIR
100
80
60
40
20
0
1600
1650
1700
1750
1800
VISUAL LAYERS
Axes
Wheat
Year
Marks
Monarchs
name Monarchs
pipeline
name Monarchs
Visual Transforms
x
start LIN X start
width 30
end LIN X end
y
start LIN Y offset
height 8
end 0
fill
color ORD Fill Color commonwealth
opacity
stroke
color
width


DATA PIPELINES
Stations
Trains
Pipeline name Trains
Import data from trains
Group by train
101 103 305 207 309 211 313 215
train 101 101 101 101
station San Jose Santa Clara Lawrence Sunnyvale
time 4:30am 4:35am 4:40am 4:44am
bound N N N N
type N N N N
mins 270 275 280 284
dist 862 805 757 731
index 0 1 2 3
1–20 of 22 (from 2,204)
Data Transforms
Scales
LIN X
LIN Y
ORD Stroke Color
Times
4 5 6 7 8 9 10 11 NOON 1
San Francisco
22nd Street
Bayshore
So. San Francisco
San Bruno
Millbrae
Broadway
Burlingame
San Mateo
Hayward Park
Hillsdale
Belmont
San Carlos
Redwood City
Atherton
Menlo Park
Palo Alto
California Ave
San Antonio
Mountain View
Sunnyvale
Lawrence
Santa Clara
College Park
San Jose
Tamien
Capitol
Blossom Hill
Morgan Hill
San Martin
VISUAL LAYERS
Layer 1
Axes
Marks
Train Stops
Trains
name Trains
pipeline
name Trains
Groups
layout Overlap
show mark once per group
Visual Transforms
type points
points
x LIN X mins
y LIN Y dist
interpolate linear
tension 0
stroke
color ORD Stroke Color type
width
Hour Rule
Hours
Station Names


DATA PIPELINES
Zip Codes
Pipeline name Zip Codes
Import data from zipcodes-full
Group by state
33 36 72 78 25 44 23 50 09
zip 00210 00211
lat +43.005895 +43.005895
lon -071.013202 -071.013202
code U U U
city PORTSMOUTH PORTSMOUTH
state 33 33 33
county 015 015 015
index 0 1 2
key 33 33 33
1–20 of 284 (from 42,192)
Data Transforms
Scales
ORD Stroke Color
VISUAL LAYERS
Visual Transforms
Geo
type Latitude/Longitude
latitude lat
longitude lon
projection mercator
center
x -98.35
y 39.50
translate
x 350
y 170
scale 775
rotate 0
precision 0
clip angle 0
output x y
type points
points
x x
y y
interpolate monotone
tension 0

DATA PIPELINES

Army

Pipeline name: Army

Import data from: army

Group by: Drop a column here. (group, dir)

Window
size: 2
step: 1

1|1 1|-1 2|1 2|-1 3|1 3|-1

lon	24	24.5	25.5	26	27
lat	54.9	55	54.6	54.7	54.8
size	340000	340000	340000	320000	300
dir	1	1	1	1	1
group	1	1	1	1	1
index	0	1	2	3	4
key	1|1	1|1	1|1	1|1	1|1

1–16 of 16 (from 49)

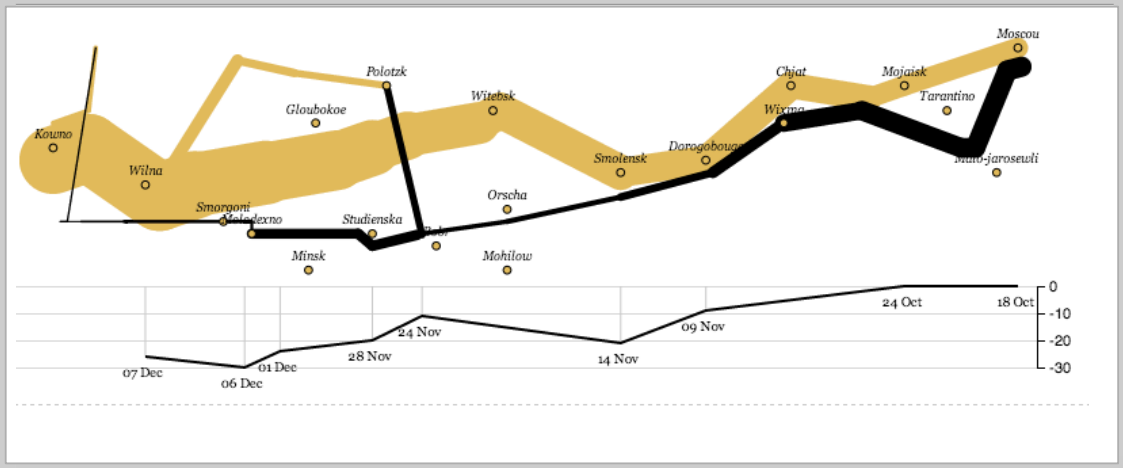
Data Transforms

Scales

ORD | Stroke Color LIN | Stroke Width

Cities

Temperatures



VISUAL LAYERS

latitude: lat

longitude: lon

projection: mercator

center
x: 32.52
y: 53.3

translate
x: 0
y: 0

scale: 3000

rotate: 0

precision: 0

clip angle: 0

output: x y

type: points

points
x: x
y: y
interpolate: monotone
tension: 0

stroke
color: ORD | Stroke Color dir