CSE 442 - Data Visualization

Visualization Tools

Jeffrey Heer  University of Washington
How do people create visualizations?
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
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
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();
}
Graphics APIs
Processing, OpenGL, Java2D
Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Data State Model

[Chi 98]
Prefuse & Flare

Operator-based toolkits for visualization design

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

Prefuse (http://prefuse.org)  Flare (http://flare.prefuse.org)
Panopoly of visualizations
Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Chart Typologies
Excel, Many Eyes, Google Charts

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
## Data Sets: State Quick Facts

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

Tags: people census

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Alabama</td>
<td>4557808</td>
<td>0.03</td>
<td>4447100</td>
<td>0.1</td>
<td>0.07</td>
<td>0.24</td>
<td>0.13</td>
</tr>
<tr>
<td>2. Alaska</td>
<td>663661</td>
<td>0.06</td>
<td>626932</td>
<td>0.14</td>
<td>0.08</td>
<td>0.29</td>
<td>0.06</td>
</tr>
<tr>
<td>3. Arizona</td>
<td>5939292</td>
<td>0.16</td>
<td>5130632</td>
<td>0.4</td>
<td>0.08</td>
<td>0.27</td>
<td>0.13</td>
</tr>
<tr>
<td>4. Arkansas</td>
<td>2779154</td>
<td>0.04</td>
<td>2673400</td>
<td>0.14</td>
<td>0.07</td>
<td>0.25</td>
<td>0.14</td>
</tr>
<tr>
<td>5. California</td>
<td>36132147</td>
<td>0.07</td>
<td>33871648</td>
<td>0.14</td>
<td>0.07</td>
<td>0.27</td>
<td>0.11</td>
</tr>
<tr>
<td>6. Colorado</td>
<td>4665177</td>
<td>0.08</td>
<td>4301261</td>
<td>0.31</td>
<td>0.07</td>
<td>0.26</td>
<td>0.1</td>
</tr>
<tr>
<td>7. Connecticut</td>
<td>3510297</td>
<td>0.03</td>
<td>3405565</td>
<td>0.04</td>
<td>0.06</td>
<td>0.24</td>
<td>0.14</td>
</tr>
<tr>
<td>8. Delaware</td>
<td>843524</td>
<td>0.08</td>
<td>783600</td>
<td>0.18</td>
<td>0.07</td>
<td>0.23</td>
<td>0.13</td>
</tr>
<tr>
<td>9. Florida</td>
<td>17789864</td>
<td>0.11</td>
<td>15982378</td>
<td>0.24</td>
<td>0.06</td>
<td>0.23</td>
<td>0.17</td>
</tr>
<tr>
<td>10. Georgia</td>
<td>9072576</td>
<td>0.11</td>
<td>8186453</td>
<td>0.26</td>
<td>0.08</td>
<td>0.26</td>
<td>0.1</td>
</tr>
<tr>
<td>11. Hawaii</td>
<td>1275194</td>
<td>0.05</td>
<td>1211537</td>
<td>0.09</td>
<td>0.07</td>
<td>0.24</td>
<td>0.14</td>
</tr>
<tr>
<td>12. Idaho</td>
<td>1429096</td>
<td>0.1</td>
<td>1293953</td>
<td>0.29</td>
<td>0.07</td>
<td>0.27</td>
<td>0.11</td>
</tr>
<tr>
<td>13. Illinois</td>
<td>12763371</td>
<td>0.03</td>
<td>12419293</td>
<td>0.09</td>
<td>0.07</td>
<td>0.26</td>
<td>0.12</td>
</tr>
</tbody>
</table>
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
Every Wednesday, when I get home from school, I have a piano lesson. My teacher is a very strict [house]. Her name is [Hillary Clinton]. Our piano is a Steinway Concert [tree] and it has 88 [cups]. It also has a soft pedal and a/an [Smily] pedal. When I have a lesson, I sit down on the piano [Alberto] and play for [16] minutes. I do scales to exercise my [cats], and then I usually play a minuet by Johann Sebastian [Washington]. Teacher says I am a natural [Haunted House] and have a good musical [leg]. Perhaps when I get better I will become a concert [veterinarian] and give a recital at Carnegie [hospital].
[M]ost charting packages channel user requests into a **rigid array of chart types**. To atone for this lack of flexibility, they offer a kit of post-creation editing tools to return the image to what the user originally envisioned. **They give the user an impression of having explored data rather than the experience.**

Leland Wilkinson
The Grammar of Graphics, 1999
Chart Typologies
Excel, Many Eyes, Google Charts

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
ggplot(diamonds, aes(x=price, fill=cut))
+ geom_bar(position="dodge")
ggplot(diamonds, aes(x=price, fill=cut)) + geom_bar(position="dodge")
qplot(long, lat, data = expo, geom = "tile", fill = ozone,
      facets = year ~ month) +
    scale_fill_gradient(low = "white", high = "black") + map
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Protovis & D3
Today's first task is not to invent wholly new [graphical] techniques, though these are needed. Rather we need most vitally to recognize and reorganize the essential of old techniques, to make easy their assembly in new ways, and to modify their external appearances to fit the new opportunities.

J. W. Tukey, M. B. Wilk
Data Analysis & Statistics, 1965
A graphic is a composition of data-representative marks.
Protovis: A Grammar for Visualization

A graphic is a composition of data-representative marks.

with Mike Bostock & Vadim Ogievetsky
MARKS: Protovis graphical primitives
<table>
<thead>
<tr>
<th>MARK</th>
<th>$\lambda : D \rightarrow R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>data</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>visible</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>left</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>bottom</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>width</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>height</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>fillStyle</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>strokeStyle</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>lineWidth</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>...</td>
<td>$\lambda$</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>data</td>
<td>1</td>
</tr>
<tr>
<td>visible</td>
<td>true</td>
</tr>
<tr>
<td>left</td>
<td>$\lambda: \text{index} \times 25$</td>
</tr>
<tr>
<td>bottom</td>
<td>0</td>
</tr>
<tr>
<td>width</td>
<td>20</td>
</tr>
<tr>
<td>height</td>
<td>$\lambda: \text{datum} \times 80$</td>
</tr>
<tr>
<td>fillStyle</td>
<td>blue</td>
</tr>
<tr>
<td>strokeStyle</td>
<td>black</td>
</tr>
<tr>
<td>lineWidth</td>
<td>1.5</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>data</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td>visible</td>
<td>true</td>
</tr>
<tr>
<td>left</td>
<td>0 * 25</td>
</tr>
<tr>
<td>bottom</td>
<td>0</td>
</tr>
<tr>
<td>width</td>
<td>20</td>
</tr>
<tr>
<td>height</td>
<td>1 * 80</td>
</tr>
<tr>
<td>fillStyle</td>
<td>blue</td>
</tr>
<tr>
<td>strokeStyle</td>
<td>black</td>
</tr>
<tr>
<td>lineWidth</td>
<td>1.5</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>RECT</td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>data</td>
<td>1 1.2 1.7 1.5 0.7</td>
</tr>
<tr>
<td>visible</td>
<td>true</td>
</tr>
<tr>
<td>left</td>
<td>1 * 25</td>
</tr>
<tr>
<td>bottom</td>
<td>0</td>
</tr>
<tr>
<td>width</td>
<td>20</td>
</tr>
<tr>
<td>height</td>
<td>1.2 * 80</td>
</tr>
<tr>
<td>fillStyle</td>
<td>blue</td>
</tr>
<tr>
<td>strokeStyle</td>
<td>black</td>
</tr>
<tr>
<td>lineWidth</td>
<td>1.5</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>RECT</td>
<td>$\lambda : D \rightarrow R$</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>data</td>
<td>1</td>
</tr>
<tr>
<td>visible</td>
<td>true</td>
</tr>
<tr>
<td>left</td>
<td>2 * 25</td>
</tr>
<tr>
<td>bottom</td>
<td>0</td>
</tr>
<tr>
<td>width</td>
<td>20</td>
</tr>
<tr>
<td>height</td>
<td>1.7 * 80</td>
</tr>
<tr>
<td>fillStyle</td>
<td>blue</td>
</tr>
<tr>
<td>strokeStyle</td>
<td>black</td>
</tr>
<tr>
<td>lineWidth</td>
<td>1.5</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>RECT</td>
<td>$\lambda : D \rightarrow R$</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>data</td>
<td>1  1.2  1.7  1.5  0.7</td>
</tr>
<tr>
<td>visible</td>
<td>true</td>
</tr>
<tr>
<td>left</td>
<td>3 * 25</td>
</tr>
<tr>
<td>bottom</td>
<td>0</td>
</tr>
<tr>
<td>width</td>
<td>20</td>
</tr>
<tr>
<td>height</td>
<td>1.5 * 80</td>
</tr>
<tr>
<td>fillStyle</td>
<td>blue</td>
</tr>
<tr>
<td>strokeStyle</td>
<td>black</td>
</tr>
<tr>
<td>lineWidth</td>
<td>1.5</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
### RECT

<table>
<thead>
<tr>
<th>data</th>
<th>1</th>
<th>1.2</th>
<th>1.7</th>
<th>1.5</th>
<th>0.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>visible</td>
<td>true</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>left</td>
<td>4 * 25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bottom</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>width</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>height</td>
<td>0.7 * 80</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fillStyle</td>
<td>blue</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>strokeStyle</td>
<td>black</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lineWidth</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RECT</td>
<td>$\lambda : D \rightarrow R$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>data</td>
<td>1</td>
<td>1.2</td>
<td>1.7</td>
<td>1.5</td>
<td>0.7</td>
</tr>
<tr>
<td>visible</td>
<td>true</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>left</td>
<td>$\lambda: \text{index} \times 25$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bottom</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>width</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>height</td>
<td>$\lambda: \text{datum} \times 80$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fillStyle</td>
<td>blue</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>strokeStyle</td>
<td>black</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lineWidth</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
var vis = new pv.Panel();
vis.add(pv.Bar)
  .data([1, 1.2, 1.7, 1.5, 0.7])
  .visible(true)
  .left((d) => this.index * 25);
  .bottom(0)
  .width(20)
  .height((d) => d * 80)
  .fillStyle("blue")
  .strokeStyle("black")
  .lineWidth(1.5);
vis.render();
var army = pv.nest(napoleon.army, "dir", "group");
var vis = new pv.Panel();

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

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

vis.add(pv.Line).data(napoleon.temp)
  .left(lon).top(tmp).strokeStyle("#0")
  .add(pv.Label)
  .top((d) => 5 + tmp(d))
  .text((d) => d.temp + "° " + d.date.substr(0,6))
  .textAlign("center").textBaseline("middle");

vis.add(pv.Label).data(napoleon.cities)
  .left(lon).top(lat)
  .text((d) => d.city).font("italic 10px Georgia")
  .textAlign("center").textBaseline("middle");
Prelude No. 1 in C Major, BWV 846
(from Well-Tempered Clavier, Book 1)

By J.S. Bach

Bach’s Prelude #1 in C Major | Jieun Oh
Obesity Map | Vadim Ogievetsky
d3.js  Data-Driven Documents

with Mike Bostock & Vadim Ogievetsky
Protovis

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

*Specify a scene (nouns)*
+ Quick for static vis
- Delayed evaluation
- Animation, interaction are more cumbersome
### Protovis

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

*Specify a scene (nouns)*
- + Quick for static vis
- - Delayed evaluation
- - Animation, interaction are more cumbersome

### D3

*Bind data to DOM*
- - Exposes SVG/CSS/…
- + Exposes SVG/CSS/…
- + Less overhead (faster)
- + Debug in browser
- + Use with other tools

*Transform a scene (verbs)*
- - More complex model
- + Immediate evaluation
- + Dynamic data, anim, and interaction natural
The core abstraction in D3 is a selection.
D3 Selections

The core abstraction in D3 is a selection.

```javascript
// Add and configure an SVG element
var svg = d3.append("svg")
  .attr("width", 500)
  .attr("height", 300);
```

// add new SVG to page body
// set SVG width to 500px
// set SVG height to 300px
D3 Selections

The core abstraction in D3 is a selection.

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

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

Selections can *bind* data and DOM elements.

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

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

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

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

Selections can *bind* data and DOM elements.

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

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

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

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

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

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

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

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

- **ENTER**: Data values without matching DOM elements.
- **UPDATE**: Existing DOM elements, bound to valid data.
- **EXIT**: DOM elements whose bound data has gone “stale”.

DATA VALUES

ELEMENTS
The Data Join

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

### ENTER
Data values without matching DOM elements.
```
s.enter().append(...)```

### UPDATE
Existing DOM elements, bound to valid data.
```
s```

### EXIT
DOM elements whose bound data has gone “stale”.
```
s.exit()```
D3 Modules

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

Many of these correspond to future lecture topics!
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Administrivia
A2: Exploratory Data Analysis

Use visualization software to form & answer questions

First steps:
1. Pick domain & data
2. Pose questions
3. Profile the data
Iterate as needed

Create visualizations
Interact with data
Refine your questions

Author a report
Screenshots of most insightful views (10+)
Include titles and captions for each view

Due by 11:59pm Monday, Oct 16
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

Author a report
Screenshots of most insightful views (10+)
Include titles and captions for each view

Due by 11:59pm Monday, Oct 16
Tutorials

Introduction to D3.js
Thursday, Oct. 19 - 5:00-6:20pm - Sieg 134
A3: Interactive Prototype

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

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

Work in project teams of 3-4 people.
Requirements

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

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

**Write-up.** Provide design rationale on your web page.
A3 & Final Project Team

Form a **team of 3-4** for A3 and the Final Project. Start thinking about your Final Project, too!

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

Submit signup form by **Friday 10/20, 11:59pm**.

**If you do not have team mates**, you should:
- Use the facilities on Canvas
- Stay after class/tutorial to meet potential partners
Team Member Roles

We encourage you to structure team responsibilities!

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

**Data Lead**: Data wrangling, management, distillation

**Tech Lead**: Manage code integration, GitHub repo

**UX Lead**: Visualization/interaction design & evaluation

*One may have multiple roles, share work across roles…*
Interactive Prototype Tips

**Start now.** It will take longer than you think.

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

**Promote engagement.** How do your chosen interactions reveal interesting observations?
A Visualization Tool Stack
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
What is a Declarative Language?
What is a Declarative Language?

Programming by describing what, not how.
What is a Declarative Language?

Programming by describing what, not how

Separate specification (what you want) from execution (how it should be computed)
What is a Declarative Language?

Programming by describing *what*, not *how*

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

In contrast to **imperative programming**, where you must give explicit steps.
What is a Declarative Language?

Programming by describing what, not how

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

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

```javascript
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); })
```
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_name
HAVING COUNT(order_id) > 5
ORDER BY COUNT(order_id) DESC
Why Declarative Languages?
Why Declarative Languages?

Faster iteration. Less code. Larger user base.
Why Declarative Languages?

Faster iteration. Less code. Larger user base.

Better visualization. *Smart defaults.*
Why Declarative Languages?

Faster iteration. Less code. Larger user base.

Better visualization. *Smart defaults.*

Reuse. *Write-once, then re-apply.*
Why Declarative Languages?

Faster iteration. Less code. Larger user base.

Better visualization. *Smart defaults.*

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

Performance. *Optimization, scalability.*
Why Declarative Languages?

Faster iteration. Less code. Larger user base.

Better visualization. *Smart defaults.*

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

Performance. *Optimization, scalability.*

Portability. *Multiple devices, renderers, inputs.*
Why Declarative Languages?

Faster iteration. Less code. Larger user base.

Better visualization. *Smart defaults.*

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

Performance. *Optimization, scalability.*

Portability. *Multiple devices, renderers, inputs.*

Programmatic generation.
*Write programs which output visualizations.*

*Automated search & recommendation.*
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Chart Typologies
Excel, Many Eyes, Google Charts

Visualization Grammars
VizQL, ggplot2, Vega-Lite
Protovis, D3.js, Vega

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D

Charting Tools
Declarative Languages
Programming Toolkits
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2, *Vega-Lite*

Visualization Grammars
Protovis, D3.js, *Vega*

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Visual Analysis Grammars
  VizQL, ggplot2, *Vega-Lite*

Visualization Grammars
  Protovis, D3.js, *Vega*

Component Architectures
  Prefuse, Flare, Improvise, VTK

Graphics APIs
  Processing, OpenGL, Java2D
Interactive Data Exploration
- Tableau, *Lyra, Polestar, Voyager*

Visual Analysis Grammars
- VizQL, ggplot2, *Vega-Lite*

Visualization Grammars
- Protovis, D3.js, *Vega*

Component Architectures
- Prefuse, Flare, Improvise, VTK

Graphics APIs
- Processing, OpenGL, Java2D