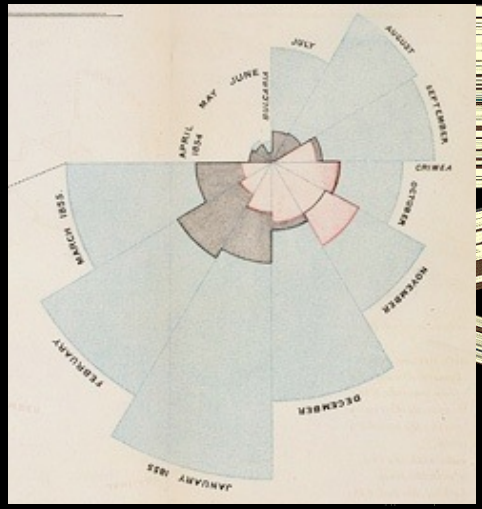
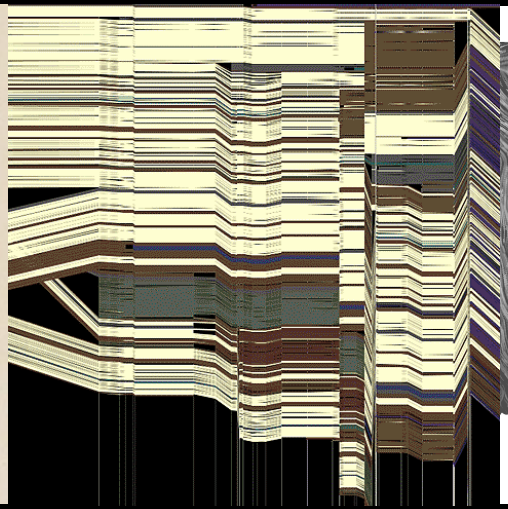
CSE 512 - Data Visualization

Visualization Tools, Part 2





Leilani Battle University of Washington

Visualization Tools

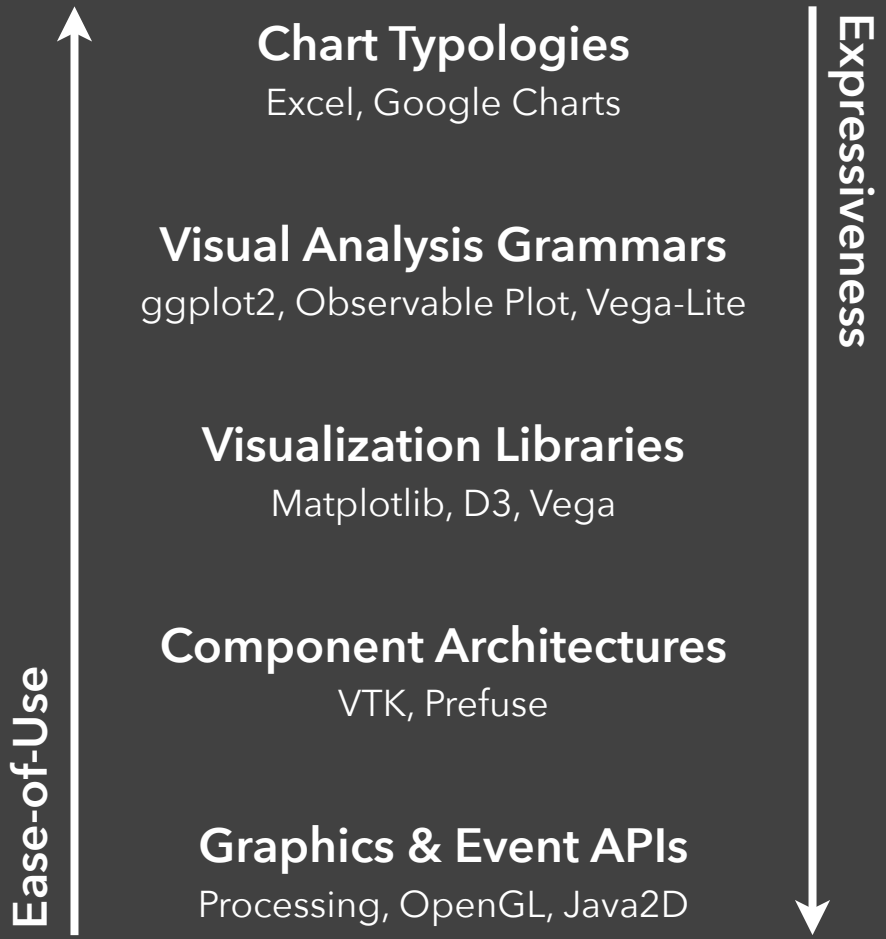


Chart Typologies
Excel, Google Charts
Visual Analysis Grammars
ggplot2, Observable Plot, Vega-Lite
Visualization Libraries
Matplotlib, D3, Vega
Component Architectures
VTK, Prefuse
Graphics & Event APIs
Processing, OpenGL, Java2D
Ease-of-Use
Expressiveness

Ease-of-Use

Expressiveness

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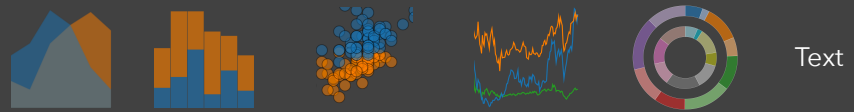
Grammar Building Blocks

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



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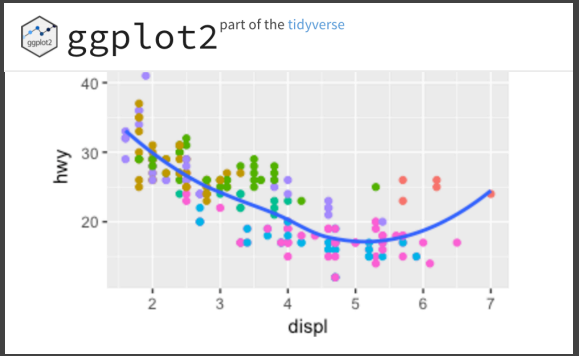

Facilitate **rapid exploration** with **concise** specifications by omitting low-level details.

Infer **sensible defaults** and customize by overriding defaults.

Ease-of-Use

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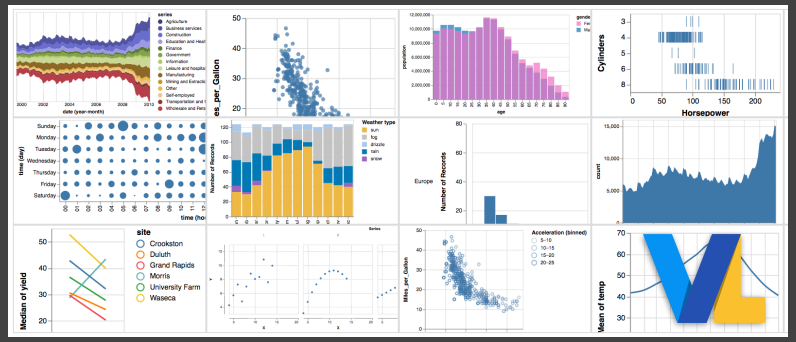

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Expressiveness

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

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

d3.js Data-Driven Documents

Mike Bostock, Vadim Ogievetsky, Jeffrey Heer [TVCG 2011]

Jason Davies (d3-geo, 2011–13), Philippe Rivière (2016–)

What is D3?

1. A collection of reusable visualization utilities
2. A tool for updating the browser's Document Object Model (DOM) in response to input data

What is D3?

1. A collection of reusable visualization utilities

   Data: d3.csv, d3.json, …

   Scales: d3.scaleLinear, d3.scaleLog, …

   Projections: d3.geoPath, d3.geoMercator, …

   Layout: d3.tree, d3.treemap, d3.force, …

   Interaction: d3.brush, d3.zoom, …

2. A tool for updating the browser's Document Object Model (DOM) in response to input data

What is D3?

1. A collection of reusable visualization utilities
2. A tool for updating the browser's Document Object Model (DOM) in response to input data

Select: query DOM content

Join: bind input data to DOM elements

Update: set DOM element properties

Transition: animate changes over time

Why D3?

Enable highly custom visualization design

Support animation and dynamic displays

Support rich and varied interactions

Interoperate via web standards (HTML, SVG, CSS)

Avoid artificial limits. If a browser can do it, D3 should be able to take advantage of it.

Why D3?

"the authors have undeniably helped to bring data visualization to the mainstream. [D3] is a cornerstone contribution to this conference specifically and more generally to the success of our field as a whole"

IEEE VIS 2021 Test of Time Award

Why D3?

D3 “slingshotted the field into growth, diversification and creativity that has been unprecedented” and “changed how millions of data visualizations are created across newsrooms, websites, and personal portfolios”

Information is Beautiful 2022 Test of Time Award

Why D3?

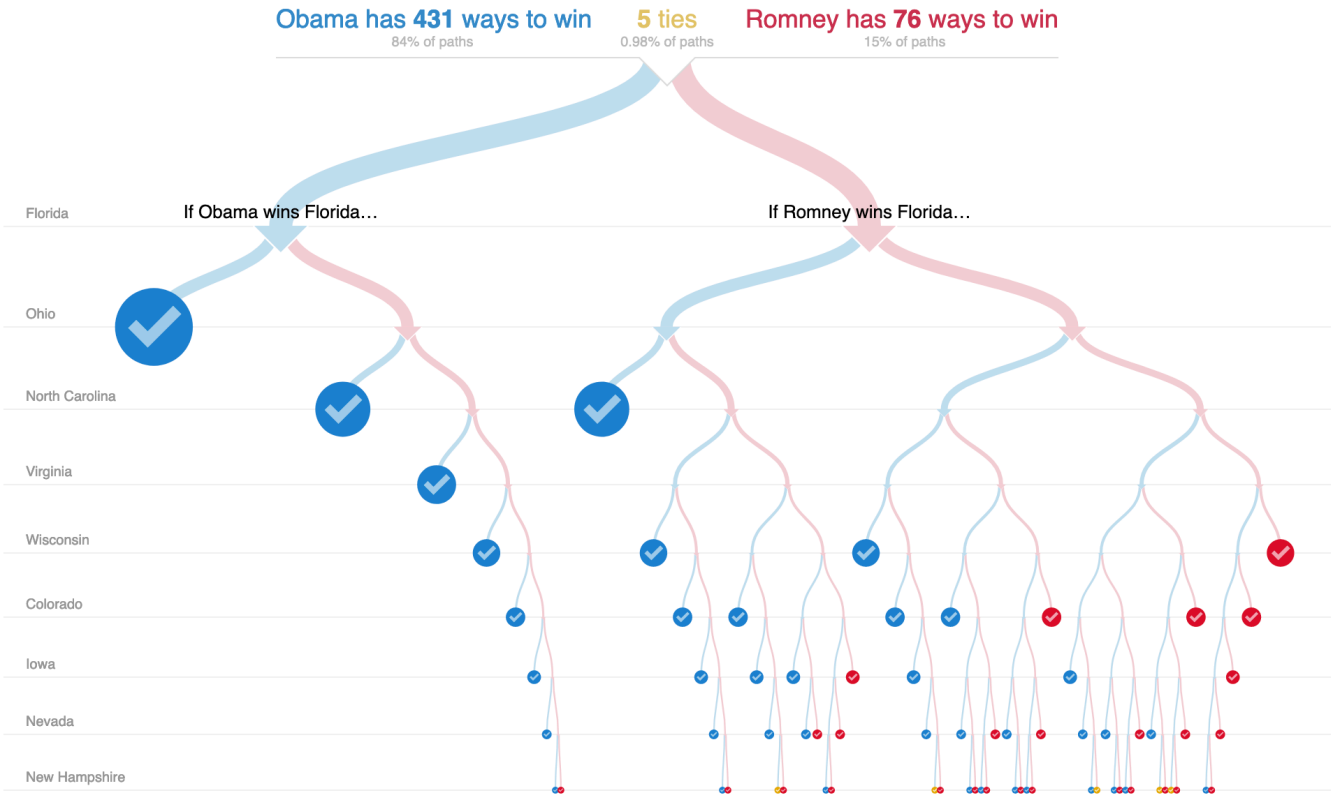
“Use D3 if you think it’s perfectly normal to write a hundred lines of code for a bar chart.”

Amanda Cox, Former Graphics Editor, NY Times

512 Paths to the White House

Select a winner in the most competitive states below to see all the paths to victory available for either candidate.

Fla.	Ohio	N.C.	Va.	Wis.	Colo.	Iowa	Nev.	N.H.
Dem Rep	Dem Rep	Dem Rep	Dem Rep	Dem Rep	Dem Rep	Dem Rep	Dem Rep	Dem Rep



D3 Selections

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

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

Data

DOM

Data

DOM

<svg width="500" …>

```
svg = d3.append("svg")
    .attr("width", 500)
    .attr("height", 300);
```

</svg>

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

DOM

<svg width="500" …>

</svg>

Data

DOM

<svg width="500" …>

svg.selectAll("rect")

???

</svg>

Data

DOM

```
<svg width="500" …>
  <rect ..></rect>
  <rect ..></rect>
  <rect ..></rect>
  <rect ..></rect>
  <rect ..></rect>
</svg>
```

Data

DOM

svg.selectAll(“rect”)

```
<svg width=“500” …>
  <rect … />
  <rect … />
  <rect … />
  <rect … />
  <rect … />
</svg>
```

Data

```
svg.selectAll(“rect”)
 .attr(“width”, 100)
 .style(“fill”, “steelblue”)
```

DOM

```
<svg width=“500” …>
 <rect width=“100”
  style=“fill: steelblue;”
 />
 <rect width=“100
  style=“fill: steelblue;”
 />
 <rect width=“100
  style=“fill: steelblue;”
```

Data Binding

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

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

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

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

Data

```
values = [
  { cat: “a”, value: 5  },
  { cat: “b”, value: 7 },
  { cat: “c”, value: 3 },
  { cat: “d”, value: 4 },
  { cat: “e”, value: 6 }
];
```

DOM

```
<svg width=500 …>




</svg>
```

Data

```
values = [
  { cat: “a”, value: 5  },
  { cat: “b”, value: 7 },
  { cat: “c”, value: 3 },
  { cat: “d”, value: 4 },
  { cat: “e”, value: 6 }
];
```

DOM

```
<svg width=500 …>
```

? ? ? ? ?

```
</svg>
```

```
bars = svg.selectAll(“rect”) .data(values)
```

Data

```
values = [
  { cat: “a”, value: 5  },
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];
```

?
?
?
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DOM

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<svg width=500 …>
</svg>
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bars = svg.selectAll(“rect”) .data(values)
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Data Binding

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

// Select SVG rectangles and bind them to data values.

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

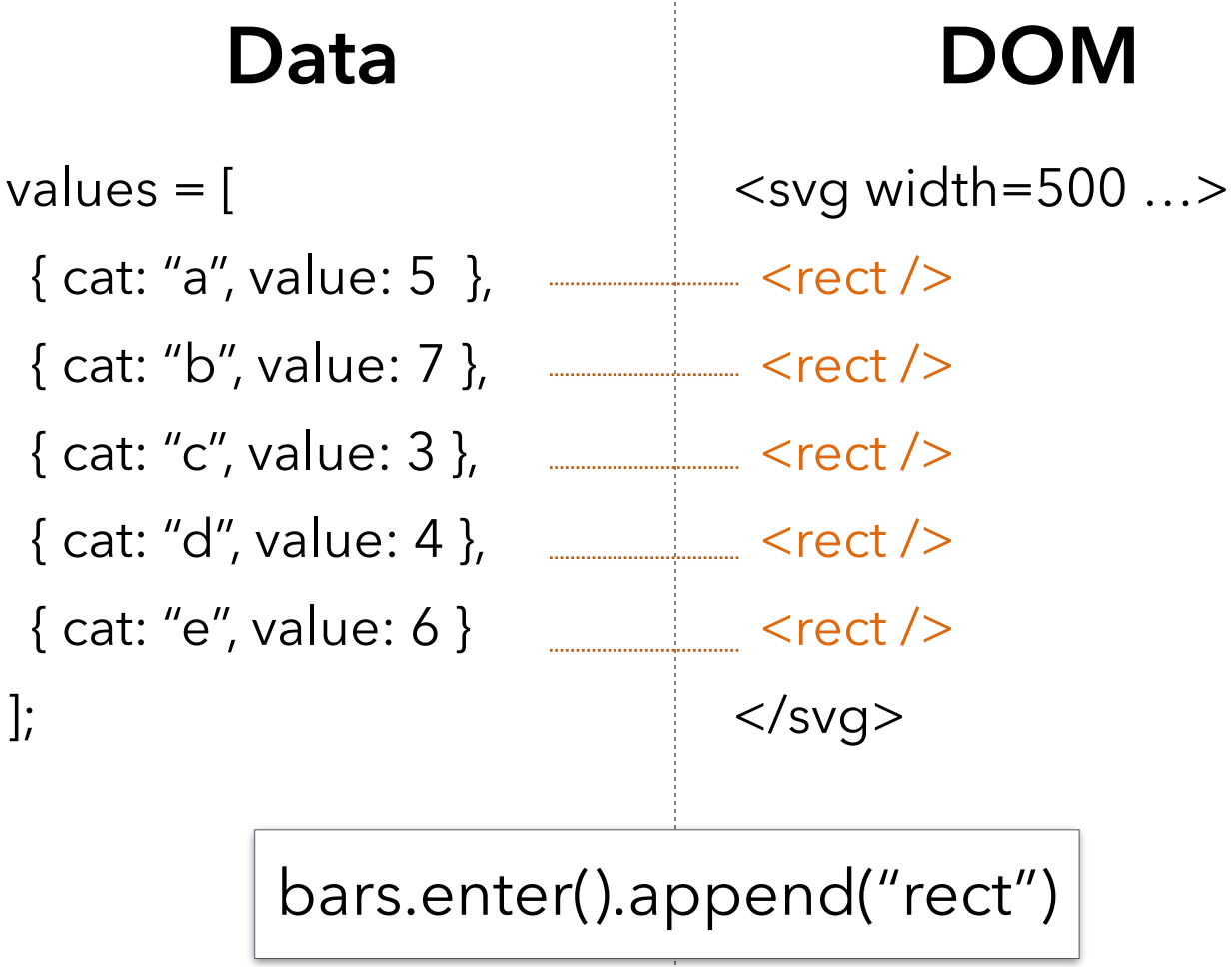
```
values = [
  { cat: “a”, value: 5  },
  { cat: “b”, value: 7 },
  { cat: “c”, value: 3 },
  { cat: “d”, value: 4 },
  { cat: “e”, value: 6 }
];
```

?
?
?
?
?

DOM

```
<svg width=500 …>
</svg>
```

```
bars = svg.selectAll(“rect”) .data(values)
```


Data
DOM
values = [
{ cat: “a”, value: 5 },
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{ cat: “c”, value: 3 },
{ cat: “d”, value: 4 },
{ cat: “e”, value: 6 }
];
<svg width=500 …>
<rect />
<rect />
<rect />
<rect />
<rect />
</svg>
bars.enter().append(“rect”)

Data

```
values = [
  { cat: “a”, value: 5  },
  { cat: “b”, value: 7 },
  { cat: “c”, value: 3 },
  { cat: “d”, value: 4 },
  { cat: “e”, value: 6 }
];
```

DOM

```
<svg width=500 …>
  <rect class=“bars” />
  <rect class=“bars” />
  <rect class=“bars” />
  <rect class=“bars” />
  <rect class=“bars” />
</svg>
```

```
bars.enter().append(“rect”).attr(“class”, “bars”)
```

Data

```
values = [
  { cat: “a”, value: 5  },
  { cat: “b”, value: 7 },
  { cat: “c”, value: 3 },
  { cat: “d”, value: 4 },
  { cat: “e”, value: 6 }
];
```

DOM

```
<svg width=500 …>
  <rect x=“…” />
  <rect x=“…” />
  <rect x=“…” />
  <rect x=“…” />
  <rect x=“…” />
</svg>
```

```
bars.enter().append(“rect”)
.attr(“x”, d => xscale(d.cat))
```

Data

```
values = [
  { cat: “a”, value: 5  },
  { cat: “b”, value: 7 },
  { cat: “c”, value: 3 },
  { cat: “d”, value: 4 },
  { cat: “e”, value: 6 }
];
```

DOM

```
<svg width=500 …>
  <rect height=“…” />
  <rect height=“…” />
  <rect height=“…” />
  <rect height=“…” />
  <rect height=“…” />
</svg>
```

```
bars.enter().append(“rect”)
.attr(“height”, d => yscale(d.value))
```

Data Binding

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

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

// Select SVG rectangles and bind them to data values.
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();
```

Data

```
values = [
  { cat: “a”, value: 5  },
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  { cat: “c”, value: 3 },
  { cat: “d”, value: 4 },
  { cat: “e”, value: 6 }
];
```

DOM

```
<svg width=500 …>
  <rect class=“bars” />
  <rect class=“bars” />
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  <rect class=“bars” />
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</svg>
```

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  { cat: “d”, value: 4 },
  { cat: “e”, value: 6 }
];
```

DOM

```
<svg width=500 …>
  <rect class=“bars” />
  <rect class=“bars” />
  <rect class=“bars” />
  <rect class=“bars” />
  <rect class=“bars” />
</svg>
```

```
values.filter(d => ![‘b’, ‘d’].includes(d.cat))
```

Data

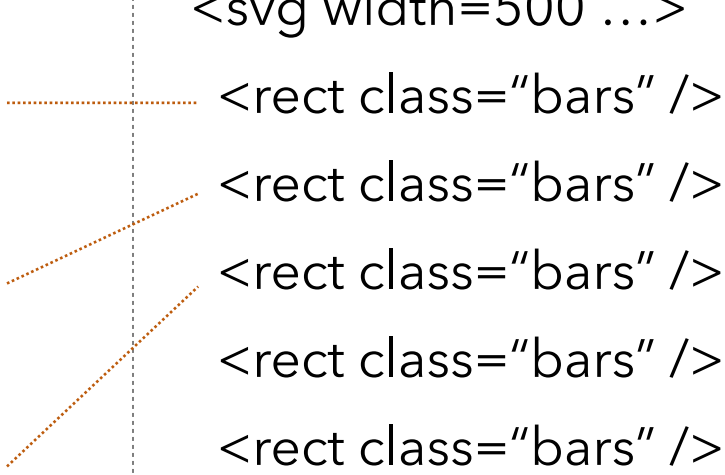
```
values = [
  { cat: “a”, value: 5  },

  { cat: “c”, value: 3 },

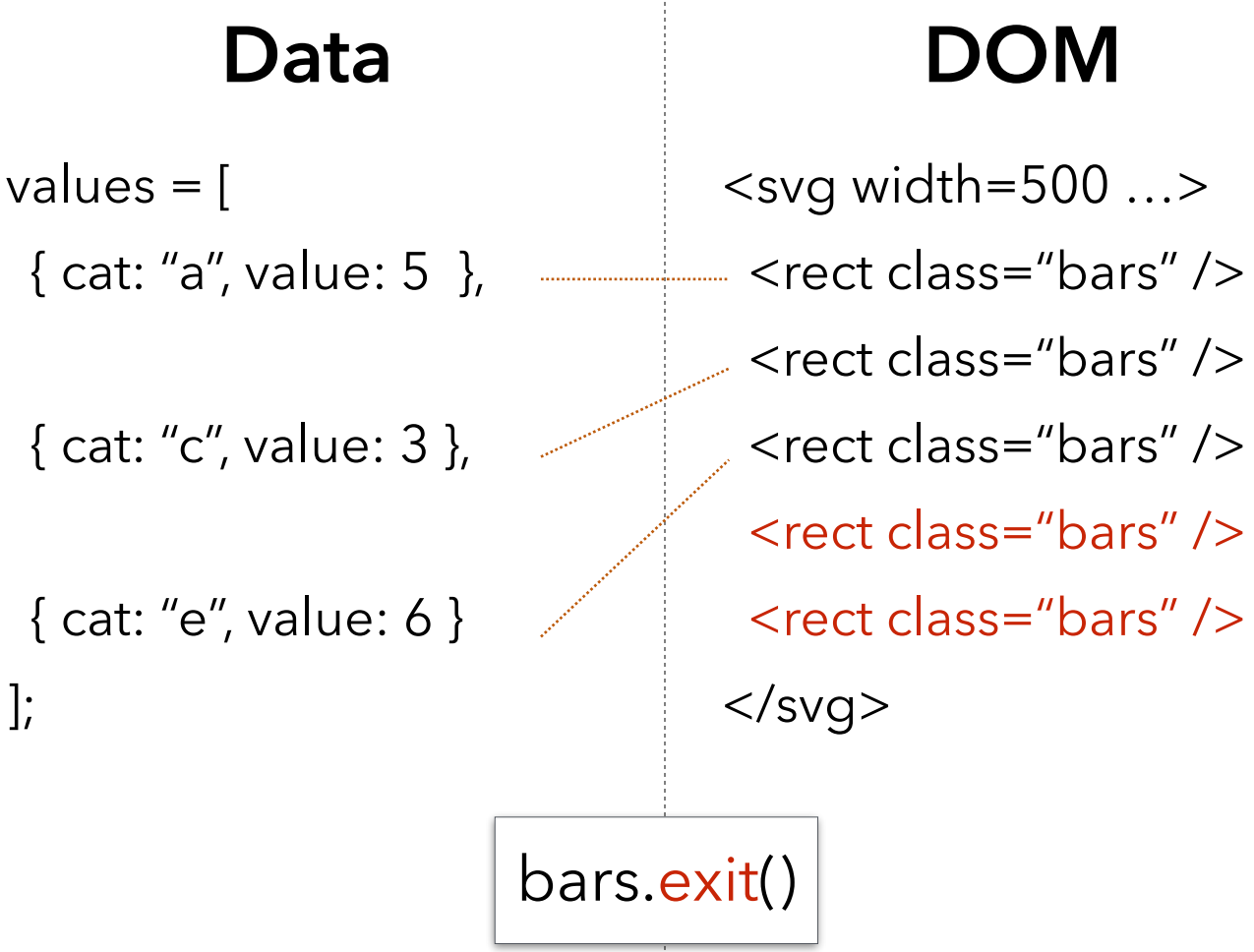
  { cat: “e”, value: 6 }
];
```

DOM

```
<svg width=500 …>
  <rect class=“bars” />
  <rect class=“bars” />
  <rect class=“bars” />
  <rect class=“bars” />
  <rect class=“bars” />
</svg>
```



```
bars = svg.selectAll(“rect.bars”).data(values)
```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<rect class=“bars” />
<rect class=“bars” />
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<rect class=“bars” />
</svg>
bars.exit()

Data

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values = [
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DOM

```
<svg width=500 …>
 <rect class=“bars” />
 <rect class=“bars” />
 <rect class=“bars” />
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 <rect class=“bars” />
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values = [
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<svg width=500 …>
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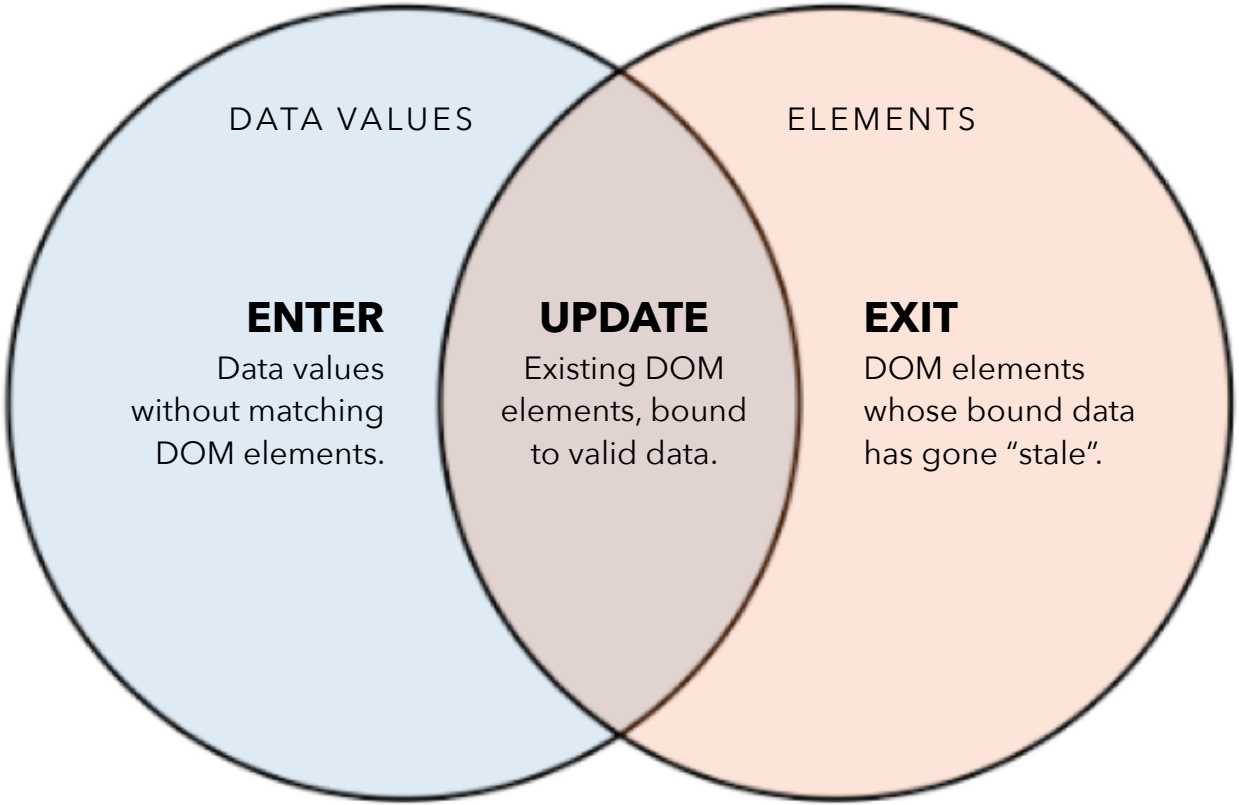
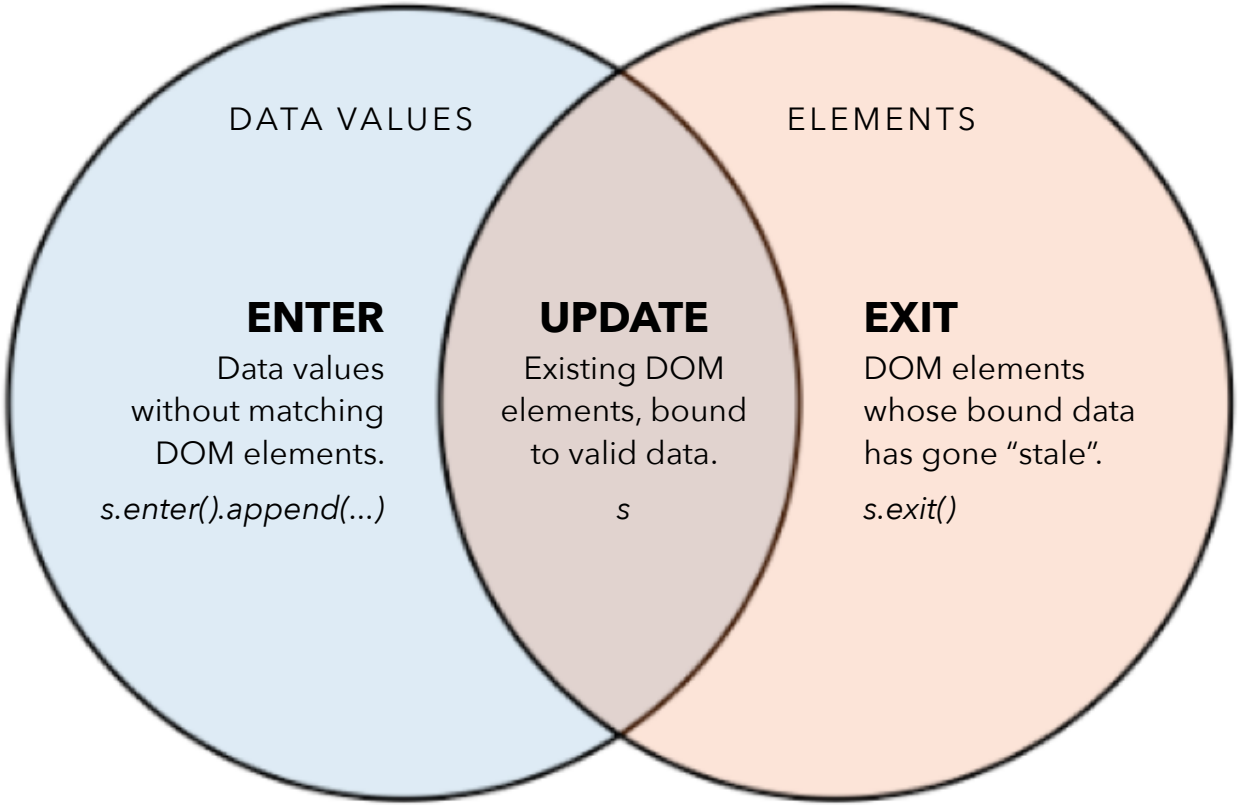
The Data Join



The Data Join

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



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// Select SVG rectangles and bind them to data values.
bars = svg.selectAll(“rect.bars”).data(values)
      .join(
            enter => enter.append("rect"), // create new
            update => update,              // update current
            exit => exit.remove()          // remove outdated
      )
```

D3 Modules

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

Many of these correspond to future lecture topics!

Administrivia

A2: Deceptive Visualization

Design **two** static visualizations for a data

1. An *earnest* visualization that co the
2. A *deceptive* visu that ewe

Your two visu dre fer ions.

sign eptive zati t appears to be
n y k yo smates and course staff?

You are to c own dataset, but we have also
ovi me preselected datasets for you.

two images and a brief write-up on Gradescope.

Due by **Mon 4/21 EOD**.

DONE

A2: Peer Reviews

You will be assigned two peer W2 submissions to review. For each:

- Try to determine which is earnest and which is deceptive
- Share a rationale for how you made this determination
- Share feedback using the “I Like / I Wish / What If” rubric

Assigned reviews will be posted to a A2 Peer Review thread on Ed, along with a link to a Google Form. You should submit two forms: one for each A2 peer review.

Due by **Tue 4/29 EOD**.

I Like… / I Wish… / What If?

I LIKE…

Praise for design ideas and/or well-executed implementation details. *Example: "I like the navigation through time via the slider; the patterns observed as one moves forward are compelling!"*

I WISH…

Constructive statements on how the design might be improved or further refined. *Example: "I wish moving the slider caused the visualization to update immediately, rather than the current lag."*

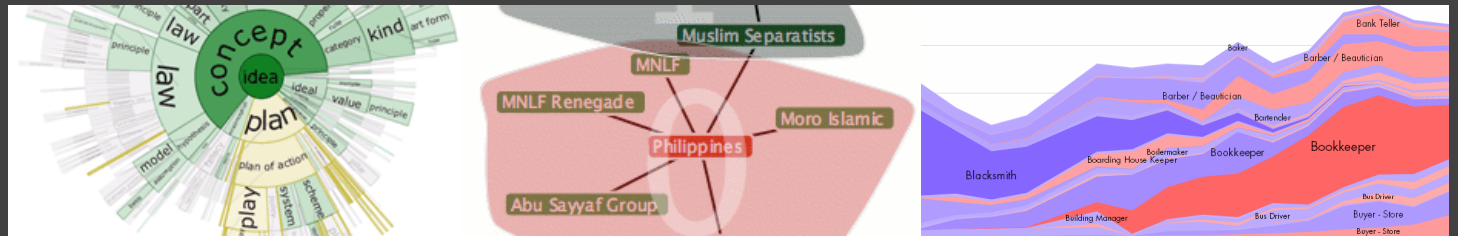
WHAT IF?

Suggest alternative design directions, or even wacky half-baked ideas. *Example: "What if we got rid of the slider and enabled direct manipulation navigation by dragging data points directly?"*

A3: Interactive Visualization

Create an interactive visualization in a team of 1-3 people. Choose a dataset and a driving question, develop a visualization + interaction techniques, then deploy your visualization on the web.

1. Form team, topic & data and start prototyping.
2. Complete implementation and submit to Gradescope by *EOD* on **Monday, May 12**.

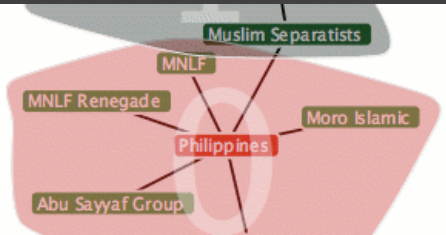


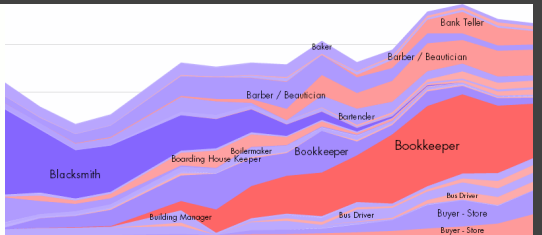
Form a Project Team

Form a **team of 1-4 people** for the A3 assignment. Submit team composition by **Friday May 2**.

If you're looking for team mates, you can post on Ed about your interests/skills/project ideas!

You may continue with the same team for the final project, or form a new team later. It's up to you.



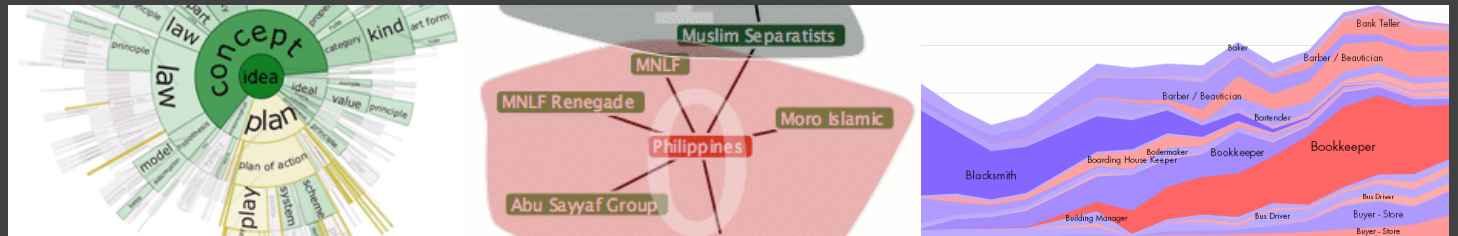


Requirements

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/Vega-Lite are encouraged, but not required. Deploy to web using GitLab pages.

Write-up. Provide design rationale.

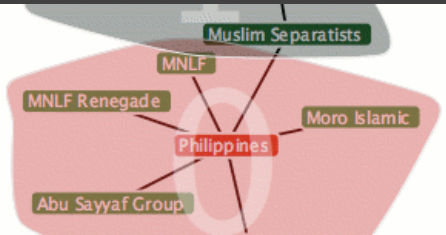


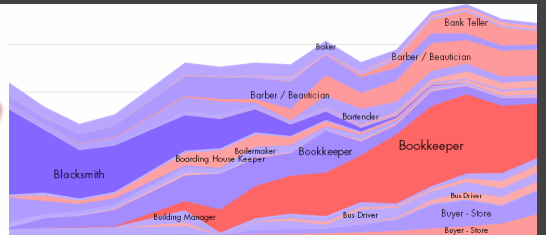
Interactive Prototype Tips

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, Vega-Lite

Visualization Grammars

D3.js, Vega

Component Architectures

Prefuse, Flare, Improvise, VTK

Graphics APIs

Canvas, OpenGL, Processing

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Graphics APIs

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Programming Toolkits

What is a Declarative Language?

Programming by describing *what*, not *how*

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

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

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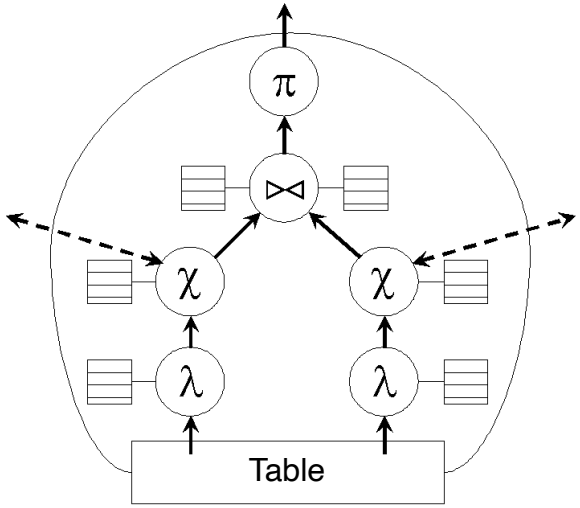
```
d3.selectAll("rect")
  .data(my_data)
 .join("rect")
  .attr("x", d => xscale(d.foo))
  .attr("y", d => yscale(d.bar))
```




```
<!DOCTYPE html PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
"http://www.w3.org/TR/html4/loose.dtd">
<!--[if IE]><![endif]-->
▼<html>
  ▶<head>…</head>
  ▼<body id="home" style="visibility: visible; ">
     <script src="http://connect.facebook.net/en_US/all.js"></scrip
     <div id="fb-root"></div>
     <a name="top"></a>
    ▼<div id="shell">
      ▶<ul id="memberTools">…</ul>
       <!-- ADXINFO classification="text_ad" campaign="nyt2010-circ-
      ▶<div class="tabsContainer">…</div>
       <!-- close .tabsContainer -->
      ▶<div id="page" class="tabContent active">…</div>
       <!--close page -->
     </div>
     <!--close shell -->
    ▶<script type="text/javascript" language="JavaScript">…</script
     <img src="/adx/bin/clientside/
     1b1a1755Q2F,.tWdC,KiQ2BCQ5C6iSM.KCYQ2FMadYYQ24xN!Q2B!xQ24WN4aN
     <script src="http://graphics8.nytimes.com/adx/bin/wt_capi.
     charset="UTF-8"></script>
     <span id="to_cr">…</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_name
HAVING COUNT(order_id) > 5
ORDER BY COUNT(order_id) DESC
```

SQL

Why Declarative Languages?

Faster iteration, less code, larger user base?

Better visualization. *Smart defaults.*

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

Performance. *Optimization, scalability.*

Portability. *Multiple devices, renderers, inputs.*

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

Chart Typologies

Excel, Many Eyes, Google Charts

Charting Tools

Visual Analysis Grammars

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

Visualization Grammars

D3.js, ***Vega***

Declarative Languages

Component Architectures

Prefuse, Flare, Improvise, VTK

Programming Toolkits

Graphics APIs

Processing, OpenGL, Java2D

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?!

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Interactive Data Exploration

Tableau, ***Lyra, Voyager***

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UW Interactive Data Lab PROJECTS

The Lyra Visualization Design Environment (VDE) alpha

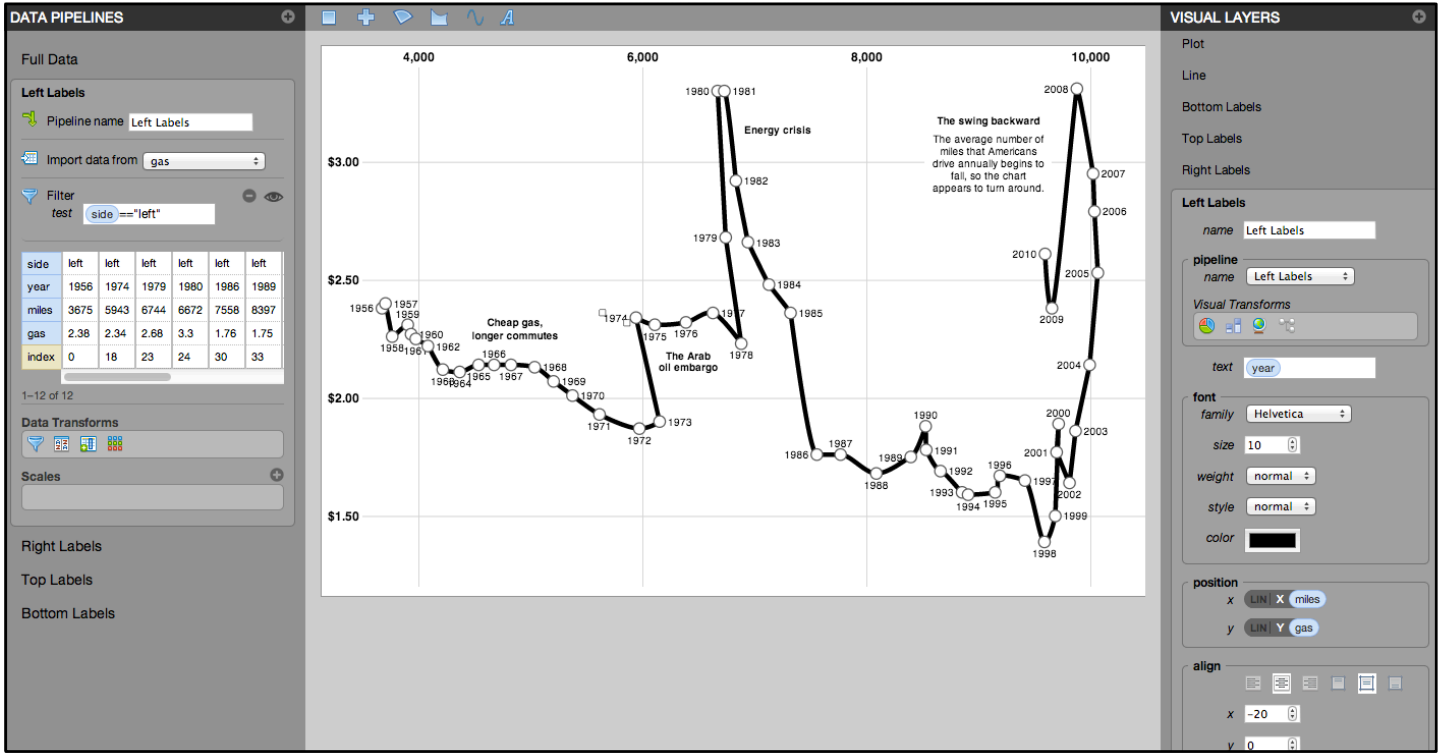
Arvind Satyanarayan, Kanit "Ham" Wongsuphasawat, Jeffrey Heer

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

idl.cs.washington.edu/projects/lyra

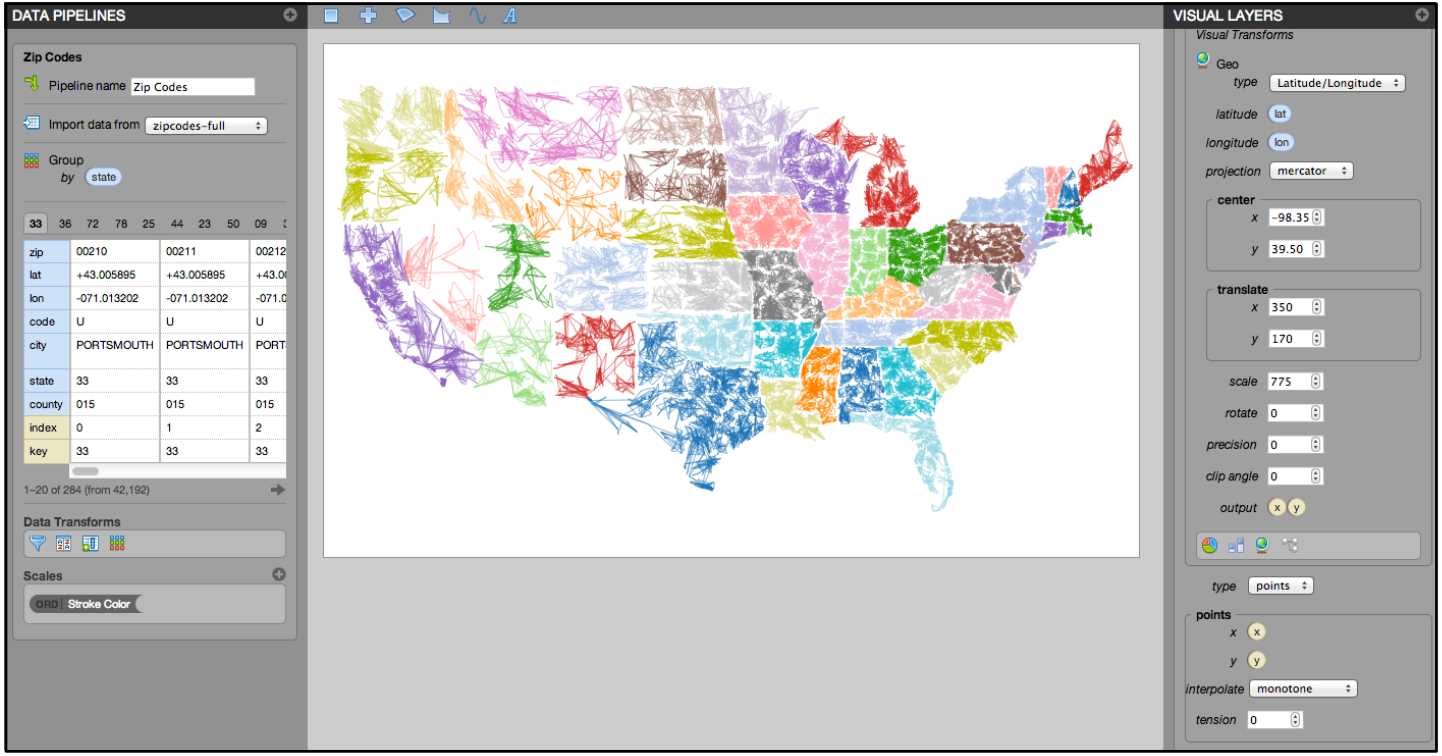
See also: Charticulator, Data Illustrator

Lyra A Visualization Design Environment



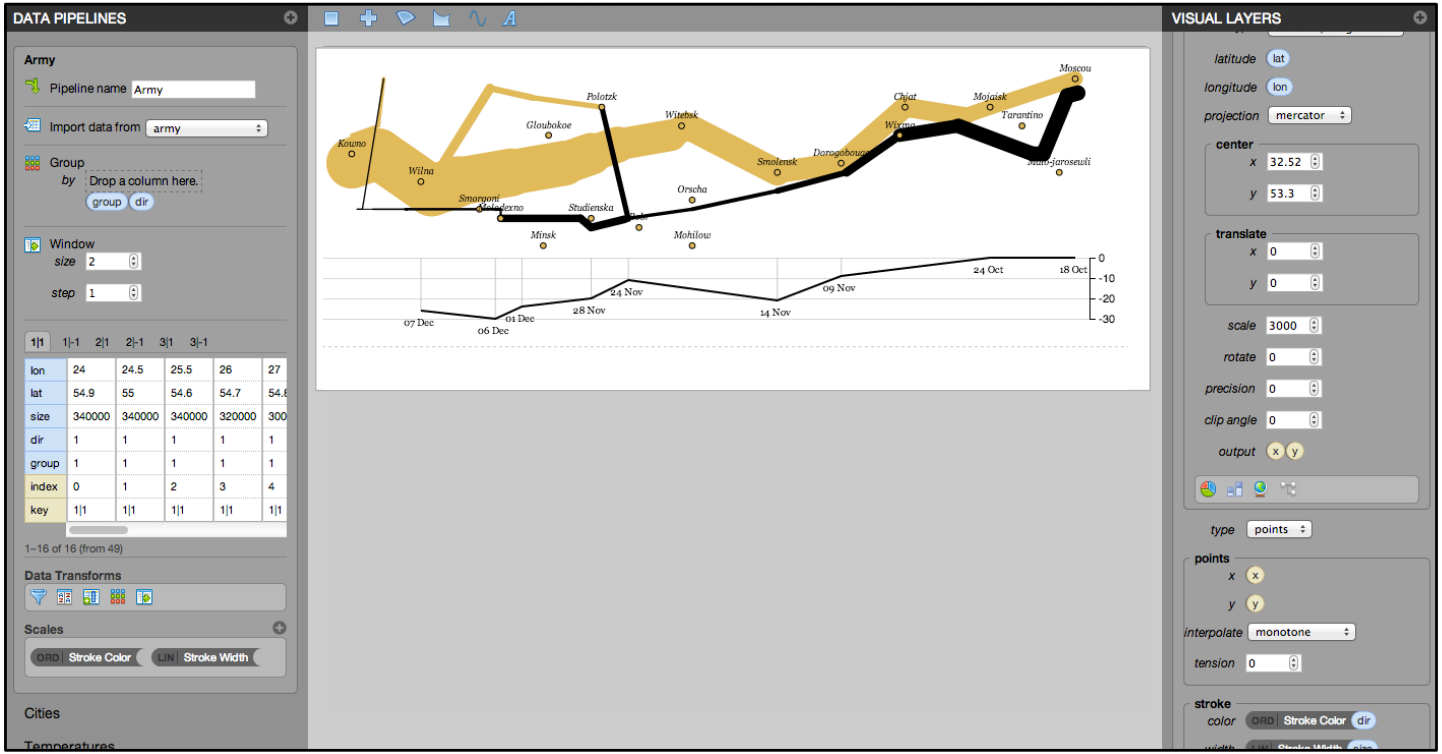
Driving Shifts into Reverse by Hannah Fairfield, NYTimes

Lyra A Visualization Design Environment



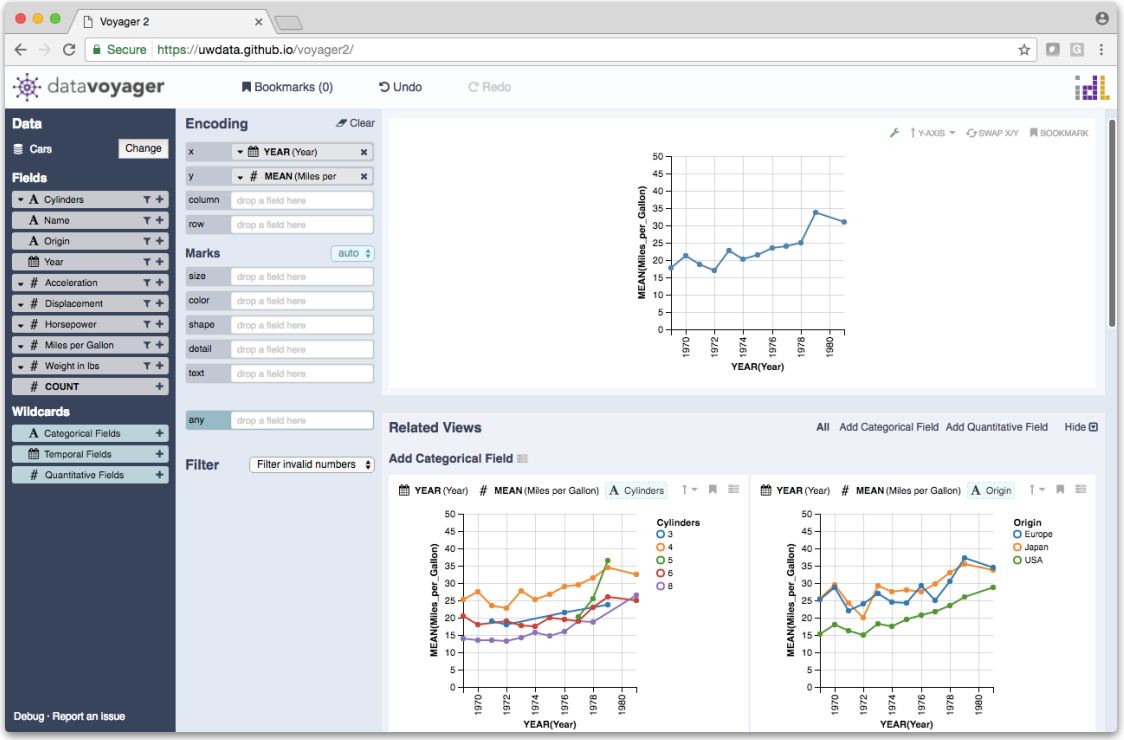
ZipScribble by Robert Kosara

Lyra A Visualization Design Environment

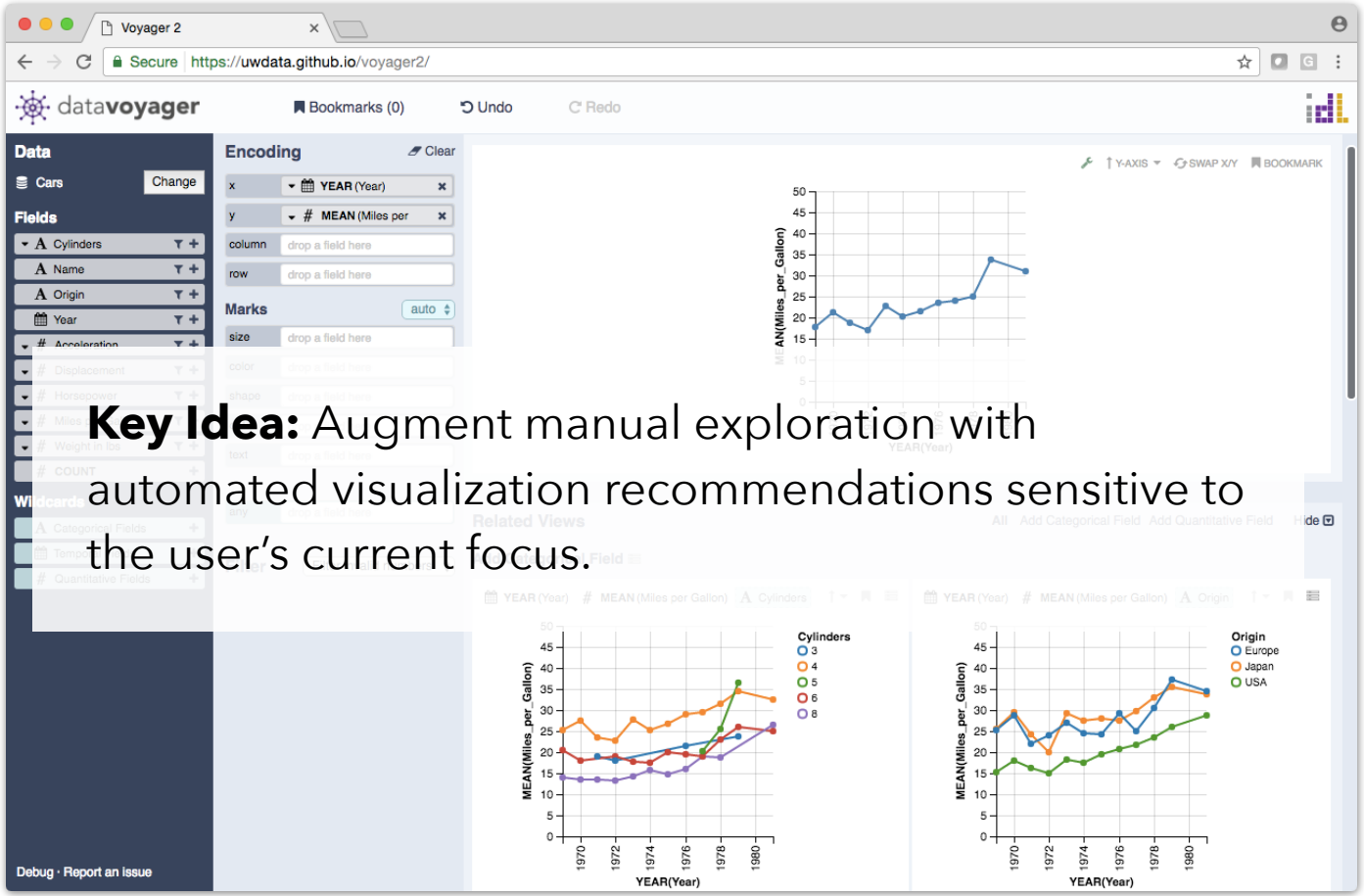


Napoleon's March by Charles Minard

Voyager Exploratory Analysis via Faceted Browsing



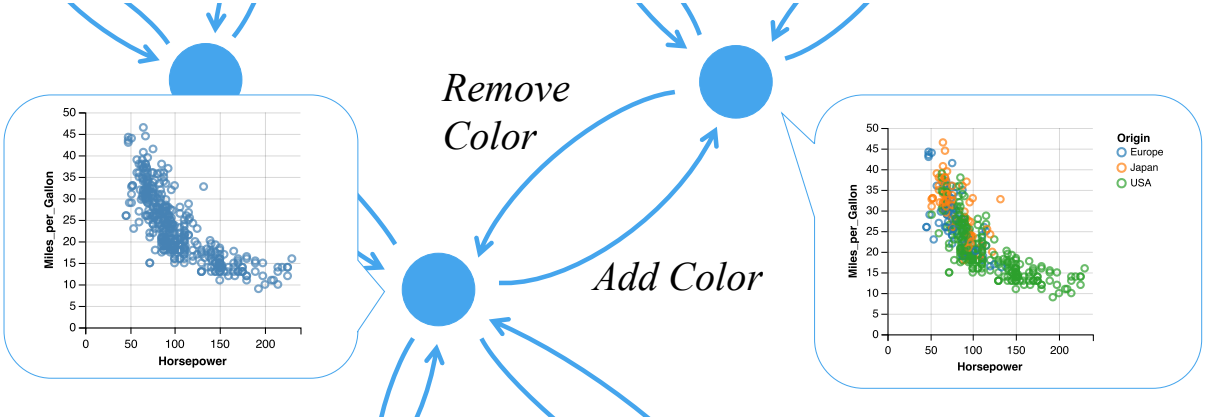
Wongsuphasawat et al. *InfoVis'15, CHI'17*



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

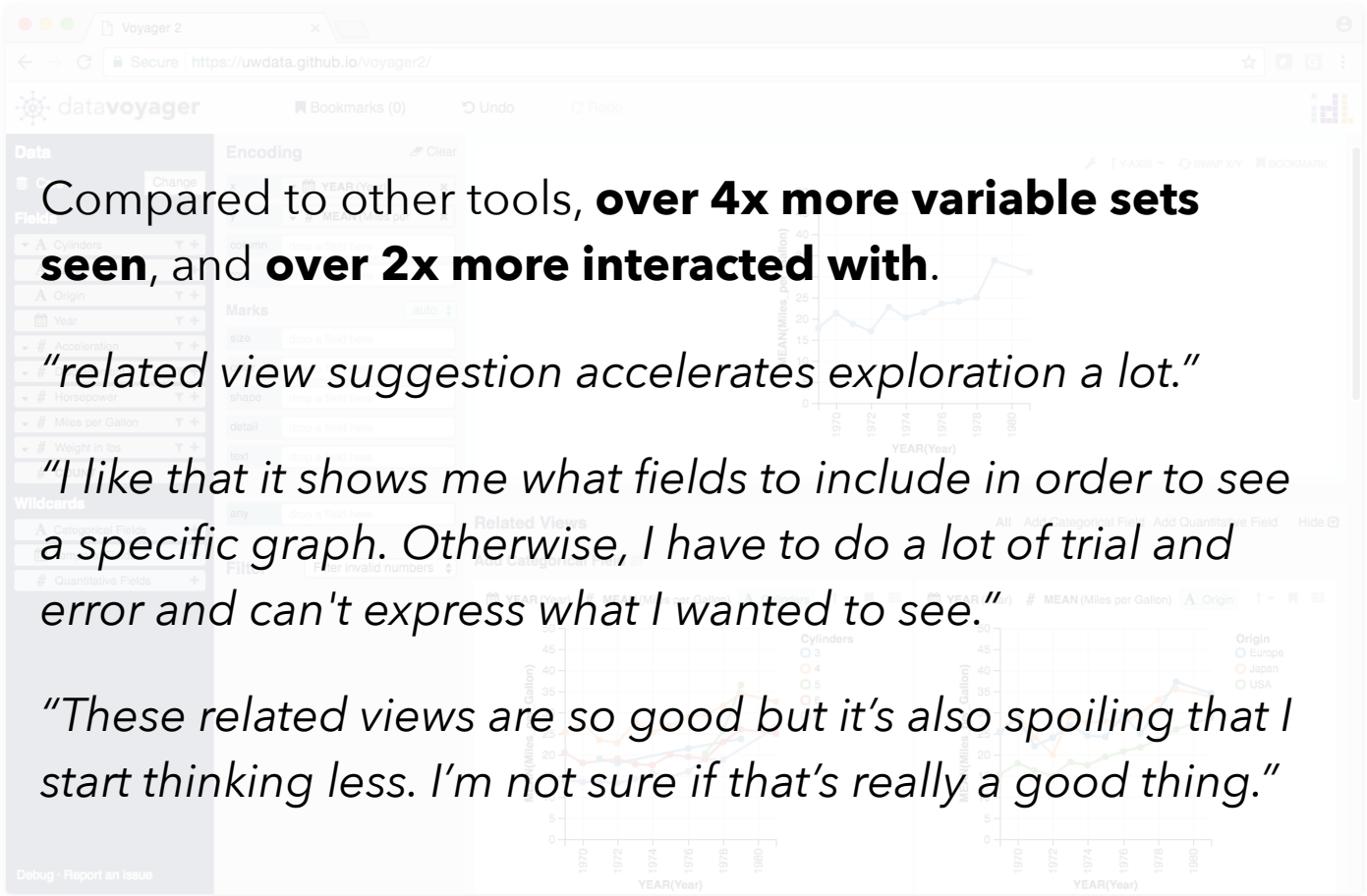
Wongsuphasawat et al. *InfoVis'15, CHI'17*

A Formal Design Space of Visualizations



Enumerate **Vega-Lite specifications** and transformations among them. Search the space using logic programming methods.

[Kim et al. 2017, Zeng et al. 2021]



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

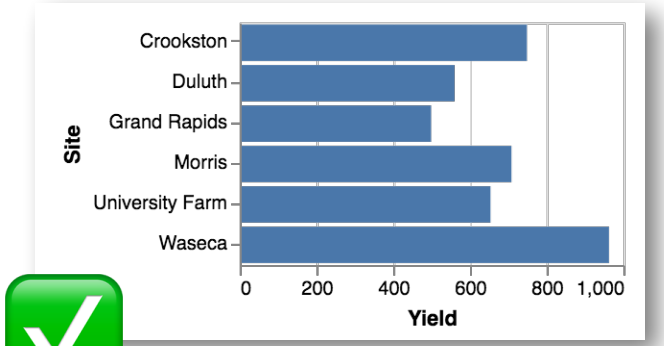
"related view suggestion accelerates exploration a lot."

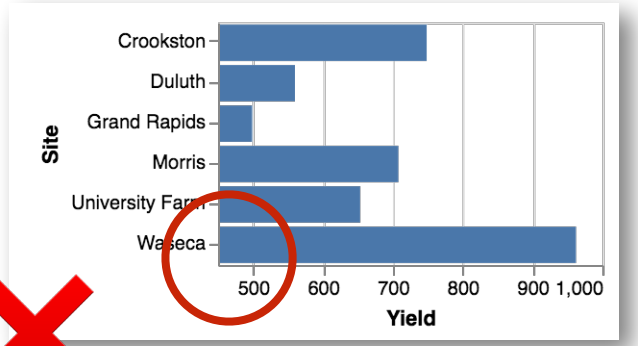
"I like that it shows me what fields to include in order to see a specific graph. Otherwise, I have to do a lot of trial and error and can't express what I wanted to see."

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

Wongsuphasawat et al. *InfoVis'15, CHI'17*

Articulate Design Constraints





"Quantitative axes should include a zero baseline"

When and how strongly should we apply this?

How to balance with other such constraints?

[Moritz et al. 2019]

Learn Design Trade-Offs from Data

Training Data

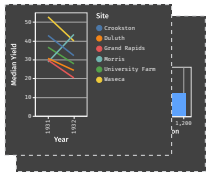
Pairs of Ranked Visualizations

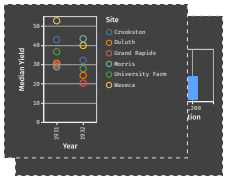
Features

Violations of Design Constraints

Learning Algorithm

Learning to Rank with Linear SVM





👍 Positive example

$[u_1, u_2, \ldots, u_k]$

👎 Negative example

$[v_1, v_2, \ldots, v_k]$

v_i: the number of violations of constraint i.

w is the weight vector of the soft constraints

$$\arg\max_w \sum_{i \in 0 \ldots k} w_i (u_i - v_i)$$

[Moritz et al. 2019]

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