IN4MATX 133: User Interface Software

Lecture 7:
TypeScript &
Data Visualization Tools

Today's goals

By the end of today, you should be able to…

- Write code which follows object-oriented principles in TypeScript
- Explain the advantages and disadvantages of using TypeScript
- Describe the concepts of threshold and ceiling in software tools and what tool designers should be striving to create
- Explain the relative threshold and ceilings of visualization tools like Protovis, D3, and Vega-Lite
- Describe common visualization primitives like marks, axes, and scales
- Implement simple visualizations with Vega-Lite

Using npm to install TypeScript

- `npm install -g typescript`
- Installs `tsc`, the TypeScript transpiler
- Could also install via HomeBrew (mac) or Chocolatey (pc)

https://www.typescriptlang.org/download

So what is TypeScript?

About TypeScript

- Released by Microsoft in 2012
- Originally only supported in Visual Studio
  - Now in Eclipse, Sublime, Webstorm, Atom, etc.
- Latest version is TypeScript 4.5, released in November 2021

About TypeScript

- Introduces static types, type checking, and objects
  - These are all optional!
- A strict superset of JavaScript
  - Syntactically-correct JavaScript will also run in TypeScript
  - Means TypeScript can use popular JavaScript libraries
- “Transcompiles” or “Transpiles” to JavaScript
  - Takes TypeScript code and converts it to equivalent JavaScript code

Typing

- hello.ts

```
var courseNumber:number = 133;

console.log('Hello, IN4MATX ' + courseNumber + '!');
```

- Transpiling: `tsc hello.ts`

- Generates hello.js

```
var courseNumber = 133;
console.log('Hello, IN4MATX ' + courseNumber + '!');
```

Typing

- Pre-defined types
  - Number
  - Boolean
  - String
  - Void (generally a function return type)
  - Null
  - Undefined
  - Any

Typing

- Typing is optional

```
var courseNumber:any = 133;
var courseNumber = 133;

console.log('Hello, IN4MATX ' + courseNumber + '!');
```

Typing

- Functions can specify argument types and return types

```
function area(shape: string, width: number, height: number)
{
    var area = width * height;
    return "I'm a " + shape + " of area " + area + " cm^2.";
}

// "better" function
function area(shape: string, width: number,
height: number):string {
    var area:number = width * height;
    return "I'm a " + shape + " of area " + area + " cm^2.";
}
```

Typing

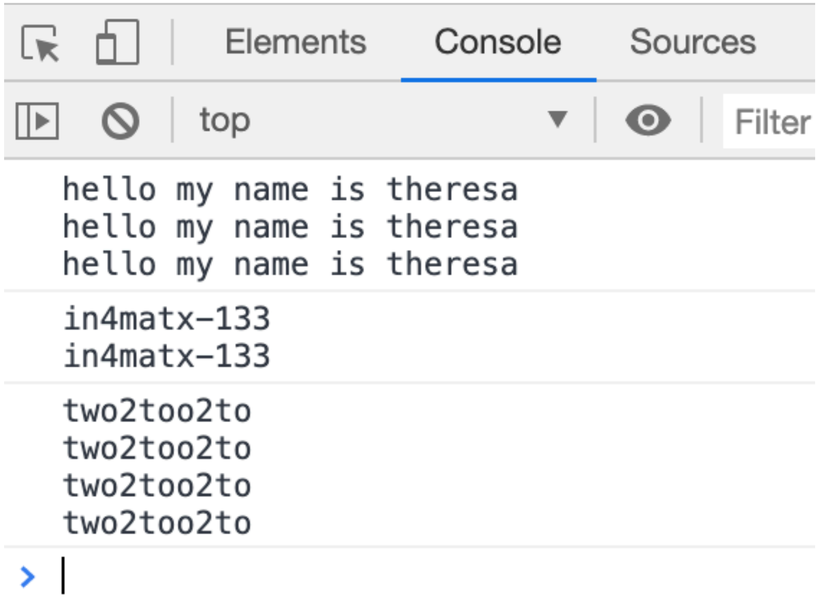
- Types enable error checking

```
// "better" function
function area(shape: string, width: number, height:
number):string {
    var area:number = width * height;
    return "I'm a " + shape + " of area " + area + "
cm^2.";
}

document.body.innerHTML = area(15, 15, 'square');
```

```
error: Argument of type ’15’ is not assignable to parameter of type ‘string’
```

Typescript demo



Question 

Which TypeScript files would transpile to

```
function pythagorean(a, b) {
    var cSq = a * a + b * b;
    return Math.sqrt(cSq);
}
```

?

A 1

B 2

C 3

D 1 and 2

E 1, 2, and 3

1

```
function pythagorean(a:number, b:number):number {
   var cSq = a*a + b*b;
   return Math.sqrt(cSq);
}
```

2

```
function pythagorean(a:number, b:number) {
   var cSq = a*a + b*b;
   return Math.sqrt(cSq);
}
```

3

```
function pythagorean(a, b) {
    var cSq = a * a + b * b;
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}
```

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(A) 1

(B) 2

(C) 3

(D) 1 and 2

(E) 1, 2, and 3

1

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3

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function pythagorean(a, b) {
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A 0%

B 0%

C 0%

D 0%

E 0%

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2

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function pythagorean(a:number, b:number) {
   var cSq = a*a + b*b;
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}
```

3

```
function pythagorean(a, b) {
    var cSq = a * a + b * b;
    return Math.sqrt(cSq);
}
```

Classes

- Also just like in Java, with a constructor and methods

```
class Shape {
    area: number;
    color: string;
    name: string;

    constructor (name: string, width: number, height: number ) {
        this.name = name
        this.area = width * height;
        this.color = "pink";
    };
    shoutout() {
        return "I'm " + this.color + " " + this.name +  " with an area of " +
this.area + " cm squared.";
    }
}

var square = new Shape("square", 30, 30);
```

Classes

- Will make a function() with prototype methods when transpiled

```
//shape.js
var Shape = /** @class */ (function () {
    function Shape(name, width, height) {
        this.name = name;
        this.area = width * height;
        this.color = "pink";
    }
    ;
    Shape.prototype.shoutout = function () {
        return "I'm " + this.color + " " + this.name + " with an area of
" + this.area + " cm squared.";
    };
    return Shape;
}());
var square = new Shape("square", 30, 30);
```

tsconfig.json

- Indicates a TypeScript project
  - Indicates what files or folders to transpile
  - Pick transpiler options, such as whether to remove comments
  - Specify what version of ECMAScript to transpile to
  - `tsc --project tsconfig.json`

https://www.typescriptlang.org/docs/handbook/tsconfig-json.html

Benefits of TypeScript

- Type checking
  - Transpiler can show warnings or errors *before* code is executed
  - Because your editor knows the types,
    it can autocomplete methods and API features
  - Easier to refactor code
- Object-oriented
  - Easier to manage/maintain large code bases
  - Simple enough to use; same principles as Java and other OO languages

Drawbacks of TypeScript

- Transpiling is occasionally a pain
  - Can be slow for large projects
- Might not work with new JavaScript libraries out of the gate
  - It took a little while for TypeScript to interface nicely with Angular and React, for example
  - Now it’s the default for Angular

Other noteworthy JavaScript transpilers

- Dart
  - Developed by Google
  - Introduces typing and similar object-oriented practices
  - Transpiles to JavaScript with dart2js

- Kotlin
  - Developed by JetBrains, who develops a lot of IDEs
  - Designed to be a “better language” than Java, but still be fully interoperable
  - Can transpile to JavaScript with kotlin.js for use with React, etc.

Software Tools and Visualization

Today is a *very* narrow slice of visualization

If you want more, take IN4MATX 143

Sequential programs (command line)

- Program takes control, prompts for input
- Person waits on the program
- Program says when it is ready for more input, which the person then provides

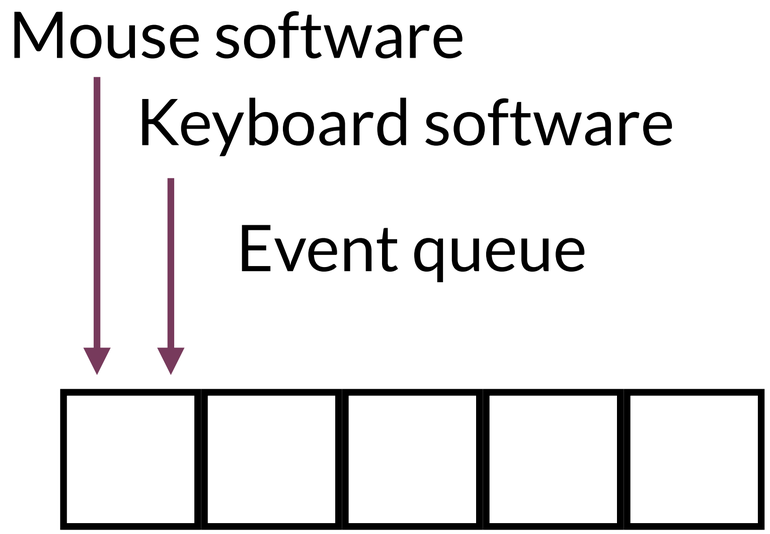
Sequential programs (command line)

```
while true {
   print “Prompt for Input”
   input = read_line_of_text()
   output = do_work()
   print output
}
```

- Person is literally modeled as a file

Event-driven programming

- A program waits for a person to provide input
- All communication is done via events
  - Mouse down, item drag, key up
- All events go in a queue
  - Ensures events are handled in order
  - Hides specifics from applications



Basic interactive software loop

- All interactive software has this loop somewhere

```
do {
  e = read_event();
  dispatch_event(e);
  if (damage_exists())
     update_display();
} while (e.type != WM_QUIT);
```

Input
Processing
Output

Basic interactive software loop

- Maybe if you've made a game, you've built this loop
- But imagine you had to write this loop every time you wanted to write a webpage, desktop app, or mobile app
- Instead, we rely on tools to handle common operations

```
do {
  e = read_event();
  dispatch_event(e);
  if (damage_exists())
     update_display();
} while (e.type != WM_QUIT);
```

Example: a button

- What's behind a button?
  - Set X and Y boundaries
  - Check if mouse down is within those boundaries
  - Check if mouse up is *also* within those boundaries
  - If so, then fire an event
- What if you had to program this sequence every time you wanted to add a button to your website?

Understanding tools

What is a user interface tool?

- Software or libraries which help you build a user interface
  - Bootstrap is a user interface tool, designed to help make interfaces responsive
  - Angular, React, etc. are all user interface tools

Understanding tools

We use tools because they…

- Identify common or important practices
- Package those practices in a framework
- Make it easy to follow those practices
- Make it easier to focus on the application we're building

Understanding tools

Tools enable…

- Faster and more iterative design
- Better implementation than without the tool
- Consistency across applications using the same tool

Understanding tools

Why is designing tools difficult?

- Need to understand the core practices and problems
- Those are often evolving with technology and design
- The tasks people are trying to solve change quickly, so tools struggle to keep up

Brad Myers, Scott E. Hudson, and Randy Pausch. TOCHI, 2000. Past, present, and future of user interface software tools. https://doi.org/10.1145/344949.344959

Understanding tools

Key terms

- Threshold: How hard to get started
- Ceiling: How much can be achieved
- Path of least resistance: Tools influence what interfaces are created
- Moving targets: Changing needs make tools obsolete

Brad Myers, Scott E. Hudson, and Randy Pausch. TOCHI, 2000. Past, present, and future of user interface software tools. https://doi.org/10.1145/344949.344959

Threshold

How hard to get started

- Some tools are harder to pick up
- Depends on what a person knows already
  - A new programming language adds to the threshold
  - If a tool borrows concepts from another popular tool, it will be easier for many people to pick up

Brad Myers, Scott E. Hudson, and Randy Pausch. TOCHI, 2000. Past, present, and future of user interface software tools. https://doi.org/10.1145/344949.344959

Ceiling

How much can be achieved

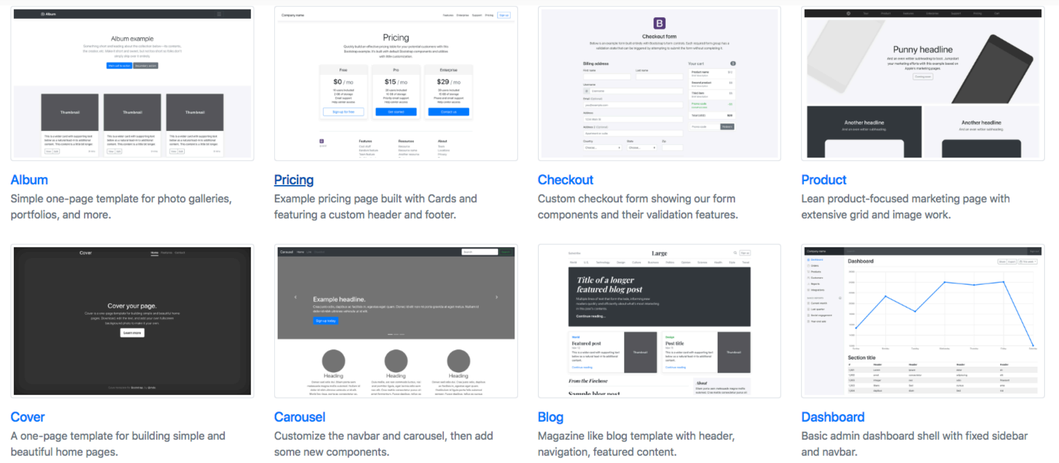
- Tools restrict what's possible
  - Your program could do much more if it had direct access to the bits on your computing device

Brad Myers, Scott E. Hudson, and Randy Pausch. TOCHI, 2000. Past, present, and future of user interface software tools. https://doi.org/10.1145/344949.344959

Path of least resistance

Tools influence what interfaces are created

- Remember the concern that all Bootstrap pages look similar?
- Sapir-Whorf Hypothesis
  - Roughly, some thoughts in one language cannot be expressed or understood in another language
- Our tools frame how we think about interaction and design



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Moving targets

Changing needs make tools obsolete

- Codification eventually constrains design
  - Our understanding of how people interact with technology improves
  - New technology comes along to change the needs of tools
  - Example: Virtual reality has wildly different interactions and tool needs

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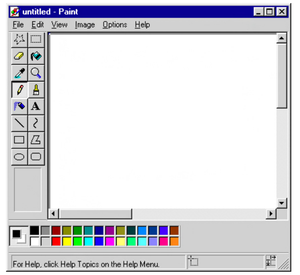
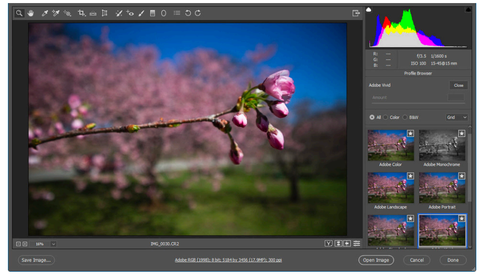
Question





ceiling

Relative to each other, what are the *threshold* and *ceiling* of Adobe Photoshop and Microsoft Paint?

(They're tools for making images, but the principles apply)

A. Photoshop: high ceiling, high threshold; Paint: low ceiling, low threshold

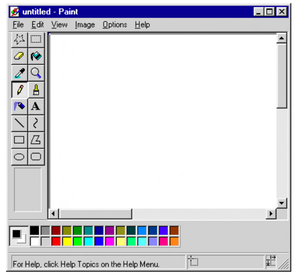
B. Photoshop: high ceiling, low threshold; Paint: low ceiling, high threshold

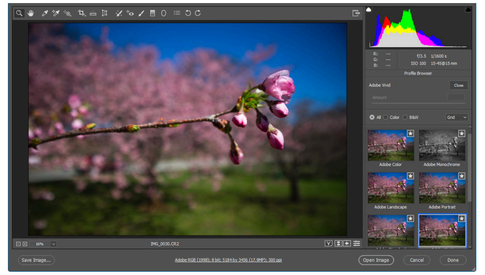
C. Photoshop: low ceiling, high threshold; Paint: high ceiling, low threshold

D. Photoshop: low ceiling, low threshold; Paint: high ceiling, high threshold

E. I'm confused, just clicking in to get participation credit

Question





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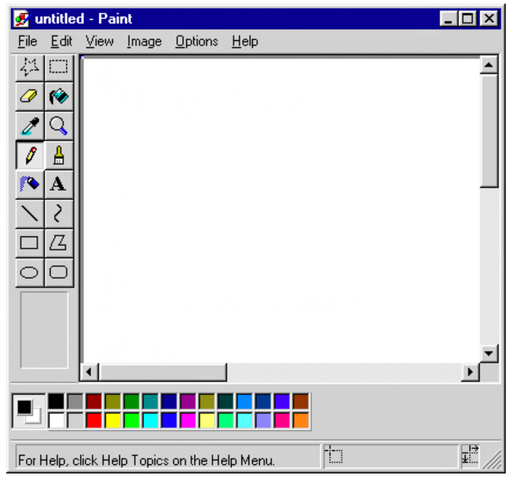
Threshold and ceiling

- It’s all relative; no absolute measure
- Tools should be *low threshold*
  - Easy to pick up
- But tools should also be *high ceiling*
  - Can do a lot
- The best tools are both
  - Photoshop introduces tutorials, etc. to lower the threshold



Ok, so what does any of this have to do with visualization?

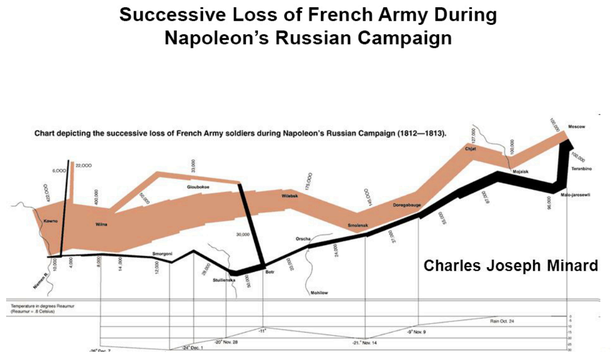
Scaleable Vector Graphics (SVG)

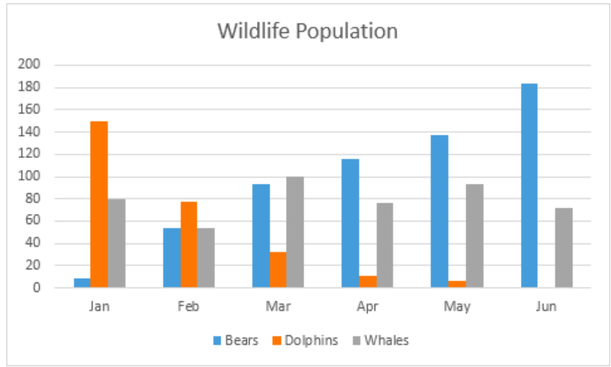
- XML format for specifying graphics
  - Looks somewhat like HTML
  - Most browsers can render them
- Composed of lines, circles, rectangles, etc.

```
<svg width="100" height="100">
  <circle cx="50" cy="50" r="40" stroke="green" stroke-
width="4" fill="yellow" />
</svg>
```

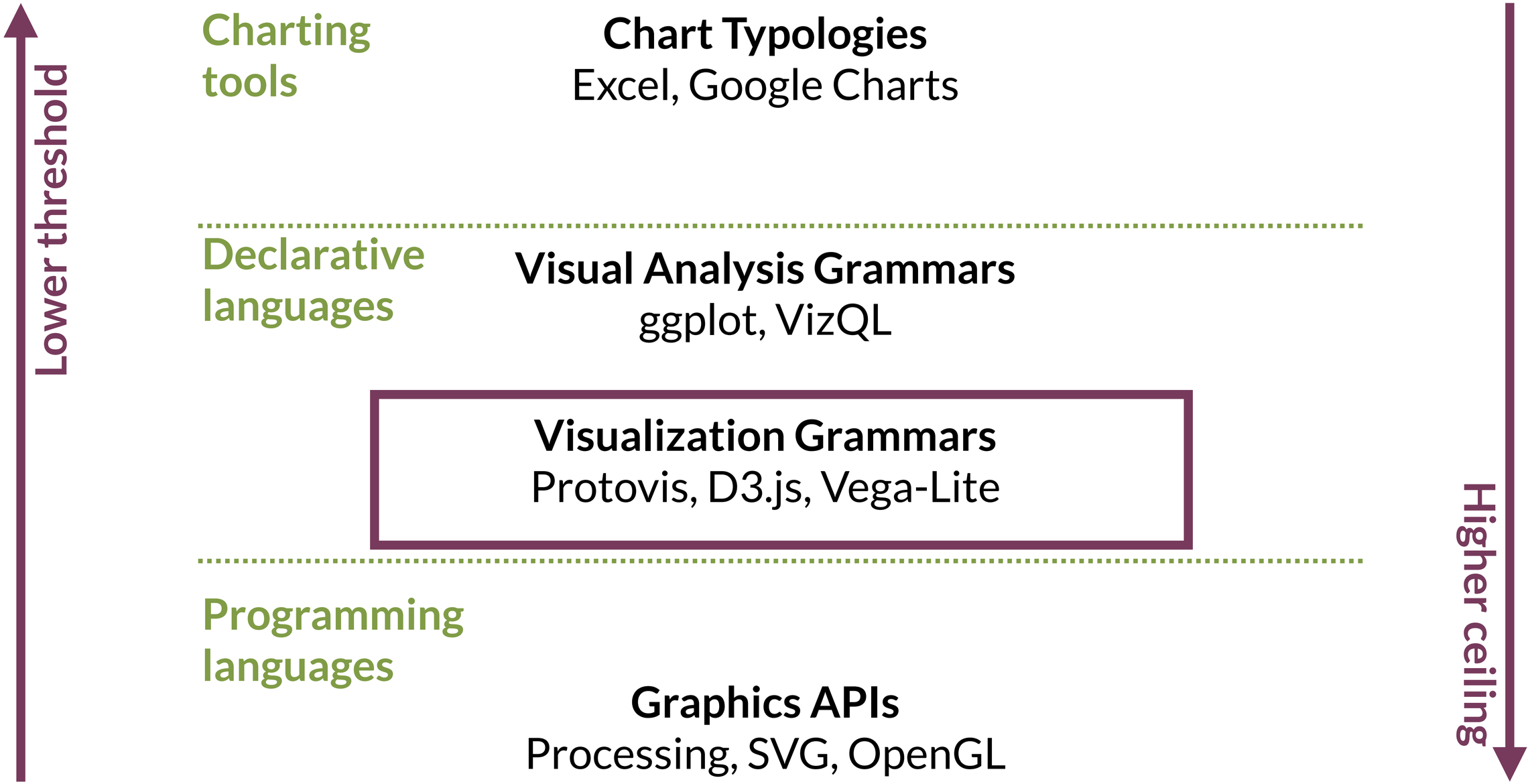
Visualization tools

- Are governed
  by the same principles
- Scaleable vector graphics (svg)
  - High ceiling, but high threshold
- Microsoft excel
  - Low threshold, but low ceiling





https://www.edwardtufte.com/tufte/posters


Lower threshold
Charting tools
Chart Typologies
Excel, Google Charts
Declarative languages
Visual Analysis Grammars
ggplot, VizQL
Visualization Grammars
Protovis, D3.js, Vega-Lite
Programming languages
Graphics APIs
Processing, SVG, OpenGL
Higher ceiling

Declarative languages

- Programming by describing *what*, not *how*
- Separate specification (*what you want*)
  from execution (*how it should be computed*)
- Contrasts to **imperative** programming, where you must give explicit steps

Declarative languages

Markup
language

Styling
language

Programming
language

Declarative languages

Declarative
language

Declarative
language

Imperative
language

Declarative languages


```
<main class="container">
  <div class="row">
    <div class="col-3">A</div>
    <div class="col-6">B</div>
    <div class="col-4">C</div>
    <div class="col">D</div>
    <div class="col">E</div>
  </div>
</main>
```

What should be rendered, but not how

```
var array = ['1', 'fish', 2, 'blue'];
array[5] = 'dog';
array.push('2');
array[2] = array[array.length - 1] - 4;
array[0] = typeof array[2];
array[4] = array.indexOf('blue');

console.log(array.join('*'));
```

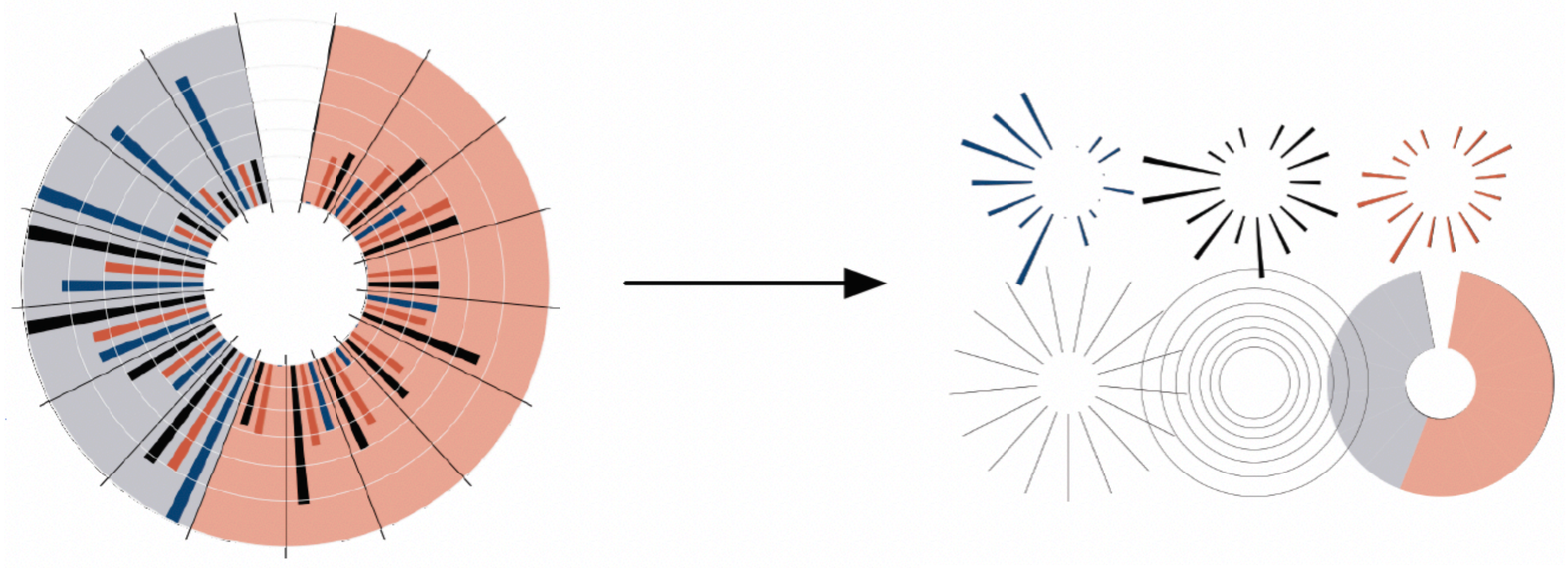
Step-by-step

Why declarative languages?

- Faster iteration, less code
  - Easier to pick up; lower threshold
- Can be generated programmatically

Protovis

- Initial grammar for visualization
- A composition of data-representative marks
  - Self-contained JavaScript model (doesn't export to SVG or anything else)



Michael Bostock, Jeffrey Heer. IEEE Vis, 2009. Protovis: A Graphical Toolkit for Visualization. https://doi.org/10.1109/TVCG.2009.174

Protovis

- Marks: graphical primitives
  - Marks specify how content should be rendered

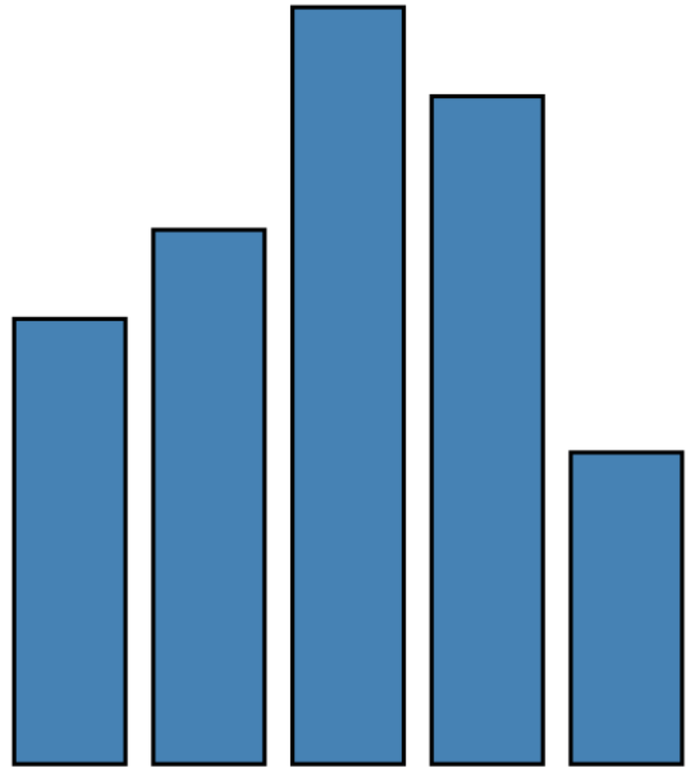
Michael Bostock, Jeffrey Heer. IEEE Vis, 2009. Protovis: A Graphical Toolkit for Visualization. https://doi.org/10.1109/TVCG.2009.174

Protovis

```
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();
```

Mark

Literally specifies which pixel each bar should start at and how many pixels tall it should be



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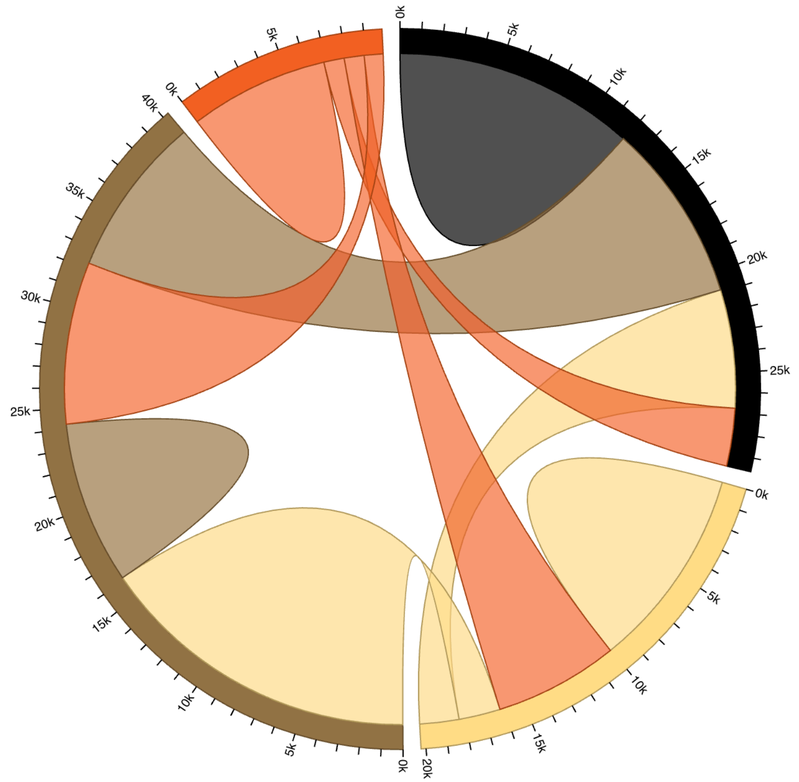
D3

- Binds data directly to a web page's DOM by editing a SVG
  - More expressive! Can make anything an SVG can make
  - Enables interactivity, can access mouse & keyboard events through the same tools as a browser
  - Much more complex…



Michael Bostock, Vadim Ogievetsky, Jeffrey Heer. IEEE Vis, 2011. D3: Data Driven Documents.
http://doi.ieeecomputersociety.org/10.1109/TVCG.2011.185

D3

```
var svg = d3.select(DOM.svg(width,
height));

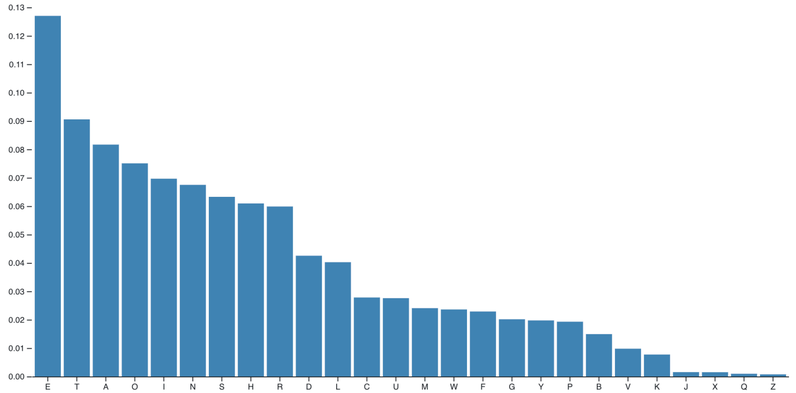
svg.append("g")
   .attr("fill", "steelblue")
.selectAll("rect").data(data).enter()
.append("rect")
   .attr("x", d => x(d.name))
   .attr("y", d => y(d.value))
   .attr("height", d => y(0) -
y(d.value))
   .attr("width", x.bandwidth());

svg.append("g")
   .call(xAxis);

svg.append("g")
   .call(yAxis);
```

Find SVG in the DOM

No more mention of marks!



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D3

```
var svg = d3.select("body").append("svg")
        .attr("width", width + margin.left + margin.right)
    .attr("height", height + margin.top + margin.bottom)
        .append("g")
    .attr("transform", "translate(" + margin.left + "," + margin.top + ")");

d3.tsv("VotingInformation.tsv", function(error, data){

          // filter year
          var data = data.filter(function(d){return d.Year == '2012';});
          // Get every column value
          var elements = Object.keys(data[0])
                    .filter(function(d){
                              return ((d != "Year") & (d != "State"));
                    });
          var selection = elements[0];

          var y = d3.scale.linear()
                              .domain([0, d3.max(data, function(d){
                                        return +d[selection];
                              })])
                              .range([height, 0]);

          var x = d3.scale.ordinal()
                              .domain(data.map(function(d){ return d.State;}))
                              .rangeBands([0, width]);


          var xAxis = d3.svg.axis()
                    .scale(x)
              .orient("bottom");

          var yAxis = d3.svg.axis()
                    .scale(y)
              .orient("left");

          svg.append("g")
          .attr("class", "x axis")
          .attr("transform", "translate(0," + height + ")")
          .call(xAxis)
          .selectAll("text")
          .style("font-size", "8px")
          .style("text-anchor", "end")
          .attr("dx", "-.8em")
          .attr("dy", "-.55em")
          .attr("transform", "rotate(-90)" );


          svg.append("g")
          .attr("class", "y axis")
          .call(yAxis);

          svg.selectAll("rectangle")
                    .data(data)
                    .enter()
                    .append("rect")
                    .attr("class","rectangle")
                    .attr("width", width/data.length)
                    .attr("height", function(d){
                              return height - y(+d[selection]);
                    })
                    .attr("x", function(d, i){
                              return (width / data.length) * i ;
                    })
                    .attr("y", function(d){
                              return y(+d[selection]);
                    })
                    .append("title")
                    .text(function(d){
                              return d.State + " : " + d[selection];
                    });

          var selector = d3.select("#drop")
          .append("select")
          .attr("id","dropdown")
          .on("change", function(d){
          selection = document.getElementById("dropdown");

          y.domain([0, d3.max(data, function(d){
                                        return +d[selection.value];})]);

          yAxis.scale(y);

          d3.selectAll(".rectangle")
                              .transition()
                    .attr("height", function(d){
                                                  return height - y(+d[selection.value]);
                                        })
                                        .attr("x", function(d, i){
                                                  return (width / data.length) * i ;
                                        })
                                        .attr("y", function(d){
                                                  return y(+d[selection.value]);
                                        })
                              .ease("linear")
                              .select("title")
                              .text(function(d){
                                        return d.State + " : " + d[selection.value];
                              });

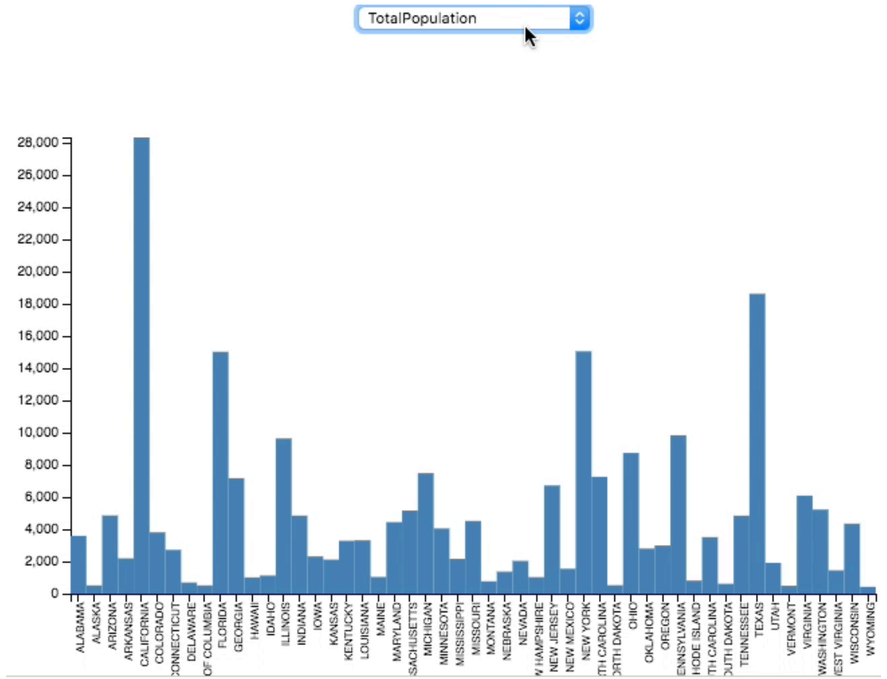
                    d3.selectAll("g.y.axis")
                              .transition()
                              .call(yAxis);

        });

    selector.selectAll("option")
      .data(elements)
      .enter().append("option")
      .attr("value", function(d){
        return d;
      })
      .text(function(d){
        return d;
      })

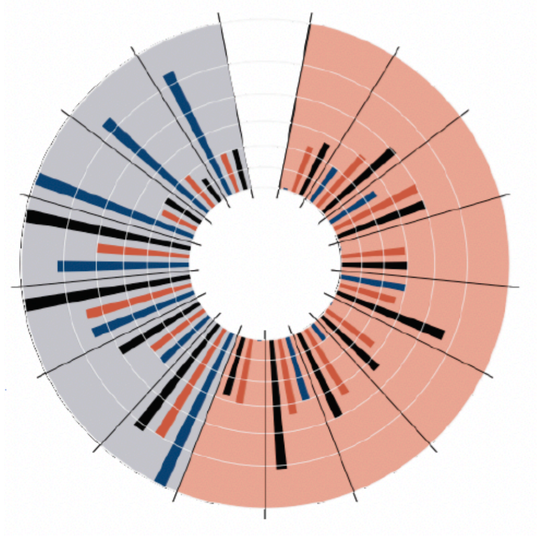
});
```

~118 lines of code,
plus data in a separate file

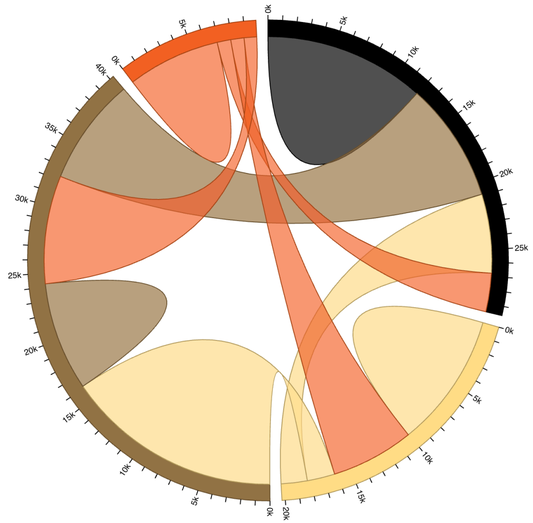


Michael Bostock, Vadim Ogievetsky, Jeffrey Heer. IEEE Vis, 2011. D3: Data Driven Documents.
http://doi.ieeecomputersociety.org/10.1109/TVCG.2011.185

Protovis & D3



Protovis
Low(er) ceiling



D3
High(er) ceiling

Compared to excel, etc., both have a high ceiling
But both have a pretty high threshold!

Vega-Lite: lowering the threshold

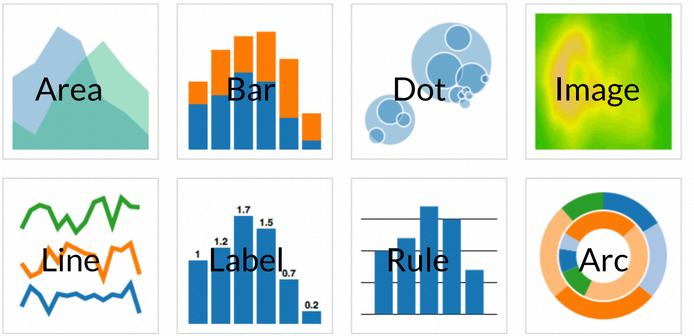
Lowering the threshold

- Goal: “create an *expressive* (high ceiling) yet *concise* (low threshold) declarative language for specifying visualizations”

Arvind Satyanarayan, Dominik Moritz, Kanit Wongsuphasawat, Jeffrey Heer. IEEE Vis, 2017. Vega-Lite: A Grammar of Interactive Graphics
https://doi.org/10.1109/TVCG.2016.2599030

Vega-Lite

- Grammar of graphics
  - Data: input data to visualize
  - Mark: Data-representative graphics
  - Transform: whether to filter, aggregate, bin, etc.
  - Encoding: mapping between data and mark properties
  - Scale: map between data values and visual values
  - Guides: axes & legends that visualize scales



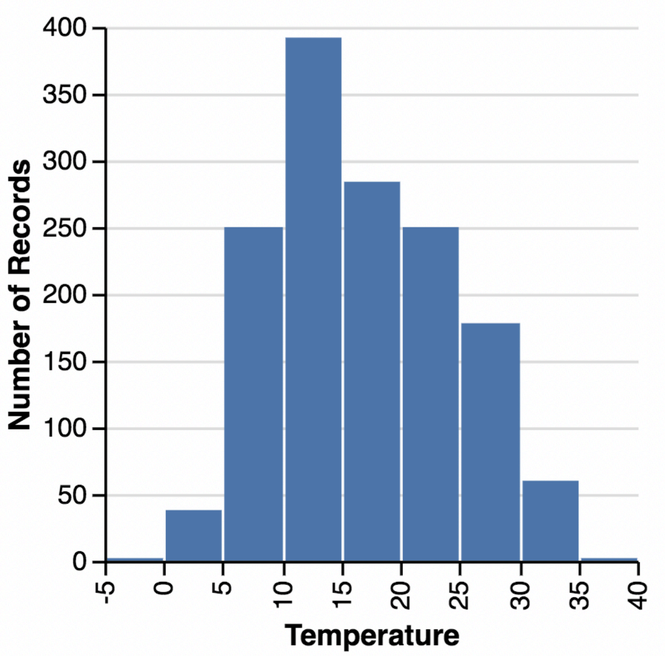
Arvind Satyanarayan, Dominik Moritz, Kanit Wongsuphasawat, Jeffrey Heer. IEEE Vis, 2017. Vega-Lite: A Grammar of Interactive Graphics
https://doi.org/10.1109/TVCG.2016.2599030

JSON file


```
[
    {
        "date": "2015/01/01",
        "weather": "sun",
        "temperature": 1.1999999999999997
    },
    {
        "date": "2015/01/02",
        "weather": "fog",
        "temperature": 2.8
    },
    {
        "date": "2015/01/03",
        "weather": "fog",
        "temperature": 3.35
    },
    {
        "date": "2015/01/04",
        "weather": "fog",
        "temperature": 6.949999999999999
    },
    {
        "date": "2015/01/05",
        "weather": "fog",
        "temperature": 10.8
    },
...
```

Vega-lite

Making a histogram

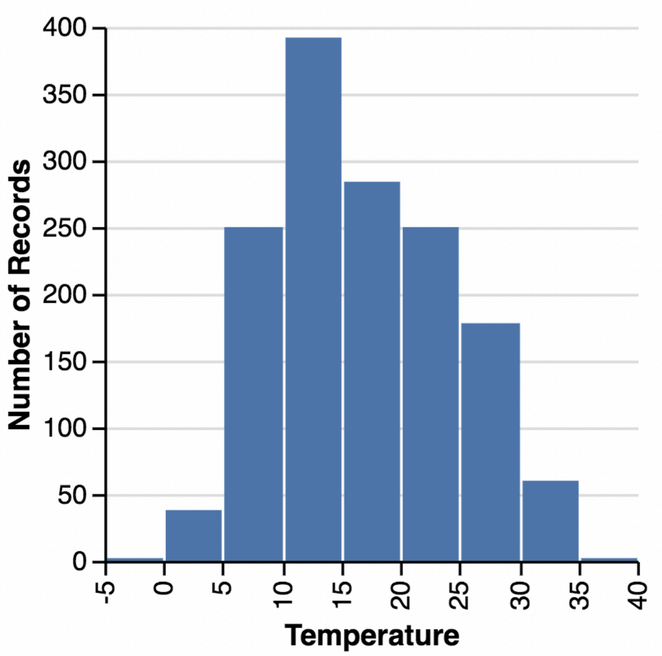


Arvind Satyanarayan, Dominik Moritz, Kanit Wongsuphasawat, Jeffrey Heer. IEEE Vis, 2017. Vega-Lite: A Grammar of Interactive Graphics
https://doi.org/10.1109/TVCG.2016.2599030

Vega-lite

Histogram = (Bar with x=binned field, y=count)

- Bin records by their temperature
- Count how many records fall into each bin
- Render those bins as vertical bars



Arvind Satyanarayan, Dominik Moritz, Kanit Wongsuphasawat, Jeffrey Heer. IEEE Vis, 2017. Vega-Lite: A Grammar of Interactive Graphics
https://doi.org/10.1109/TVCG.2016.2599030

Vega-lite

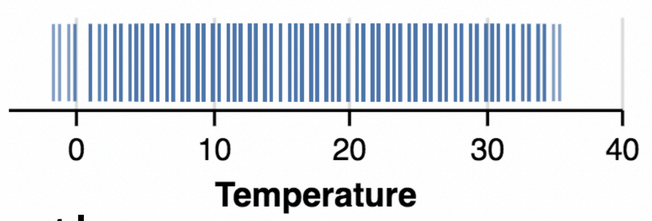
Histogram = (Bar with x=binned field, y=count)

```
{
  data: {url: "weather-seattle.json"},
  mark: "tick",
  encoding: {
    x: {
      field: "temperature",
      type: "quantitative"
    }
  }
}
```

Set mark as a tick

Encode x according to the “temperature” field

Four types:
quantitative (numerical)
temporal (time)
ordinal (ordered)
nominal (categorical)



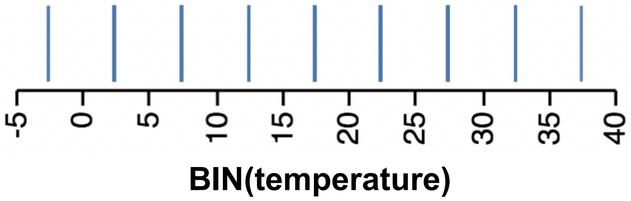
Arvind Satyanarayan, Dominik Moritz, Kanit Wongsuphasawat, Jeffrey Heer. IEEE Vis, 2017. Vega-Lite: A Grammar of Interactive Graphics
https://doi.org/10.1109/TVCG.2016.2599030

Vega-lite

Histogram = (Bar with x=binned field, y=count)

```
{
  data: {url: "weather-seattle.json"},
  mark: "tick",
  encoding: {
    x: {
      bin: true,
      field: "temperature",
      type: "quantitative"
    }
  }
}
```

← Bin values by x dimension



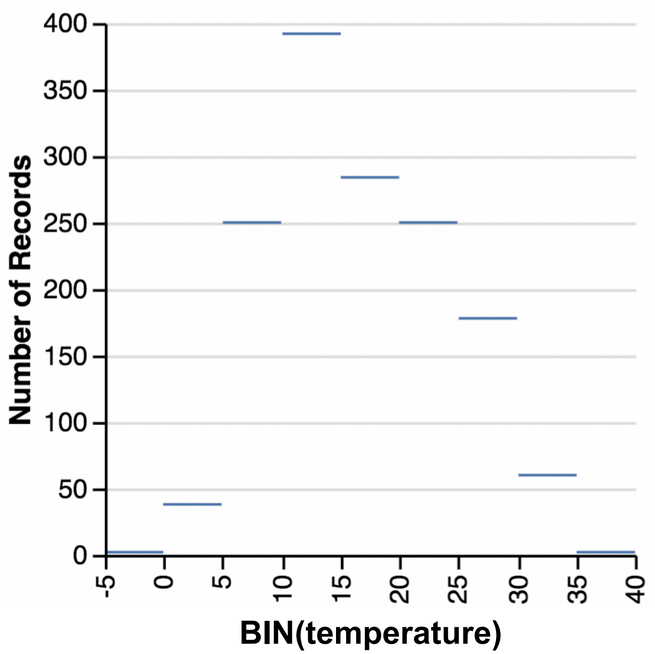
Arvind Satyanarayan, Dominik Moritz, Kanit Wongsuphasawat, Jeffrey Heer. IEEE Vis, 2017. Vega-Lite: A Grammar of Interactive Graphics
https://doi.org/10.1109/TVCG.2016.2599030

Vega-lite

Histogram = (Bar with x=binned field, y=count)

```
{
  data: {url: "weather-seattle.json"},
  mark: "tick",
  encoding: {
    x: {
      bin: true,
      field: "temperature",
      type: "quantitative"
    },
    y: {
      aggregate: "count",
      type: "quantitative"
    }
  }
}
```

y should aggregate the bins by counting how many values are in them



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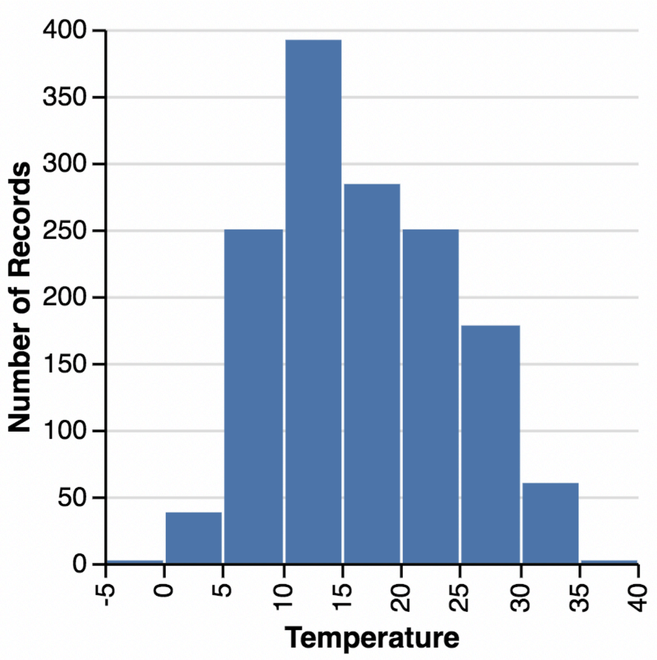
https://doi.org/10.1109/TVCG.2016.2599030

Vega-lite

Histogram = (Bar with x=binned field, y=count)

```
{
  data: {url: "weather-seattle.json"},
  mark: "bar",
  encoding: {
    x: {
      bin: true,
      field: "temperature",
      type: "quantitative"
    },
    y: {
      aggregate: "count",
      type: "quantitative"
    }
  }
}
```

← Change the mark to a bar



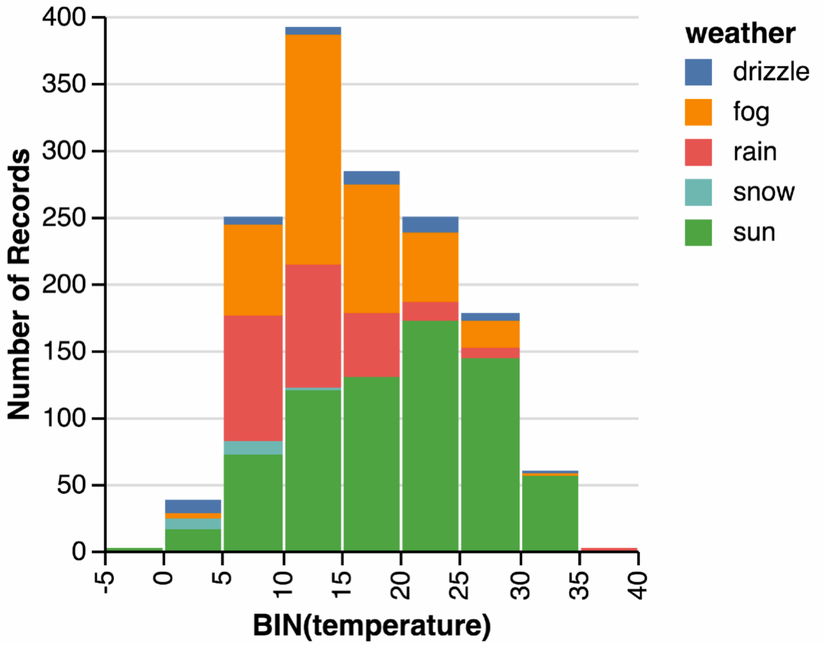
Arvind Satyanarayan, Dominik Moritz, Kanit Wongsuphasawat, Jeffrey Heer. IEEE Vis, 2017. Vega-Lite: A Grammar of Interactive Graphics
https://doi.org/10.1109/TVCG.2016.2599030

Vega-lite

Histogram + Color

```
{
  data: {url: "weather-seattle.json"},
  mark: "bar",
  encoding: {
    x: {
      bin: true,
      field: "temperature",
      type: "quantitative"
    },
    y: {
      aggregate: "count",
      type: "quantitative"
    },
    color: {
      field: "weather",
      type: "nominal"
    }
  }
}
```

Set the color to follow the weather

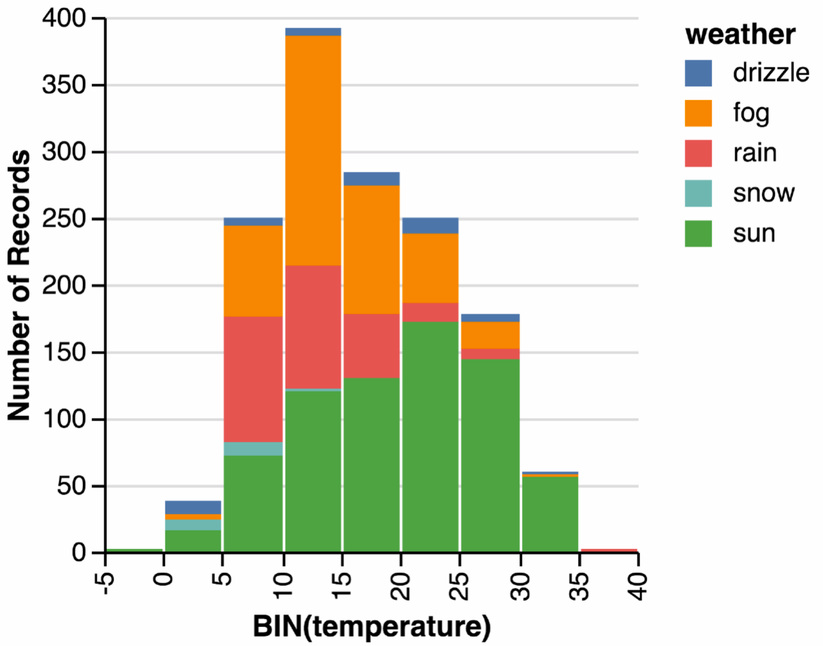


Arvind Satyanarayan, Dominik Moritz, Kanit Wongsuphasawat, Jeffrey Heer. IEEE Vis, 2017. Vega-Lite: A Grammar of Interactive Graphics
https://doi.org/10.1109/TVCG.2016.2599030

Vega-lite

“Sensible defaults”

- The field chose reasonable defaults for presenting the data
  - We didn’t specify what colors to use
  - Or how wide bins should be
  - Or how to label the axes
  - Or that the bars should be stacked
  - …



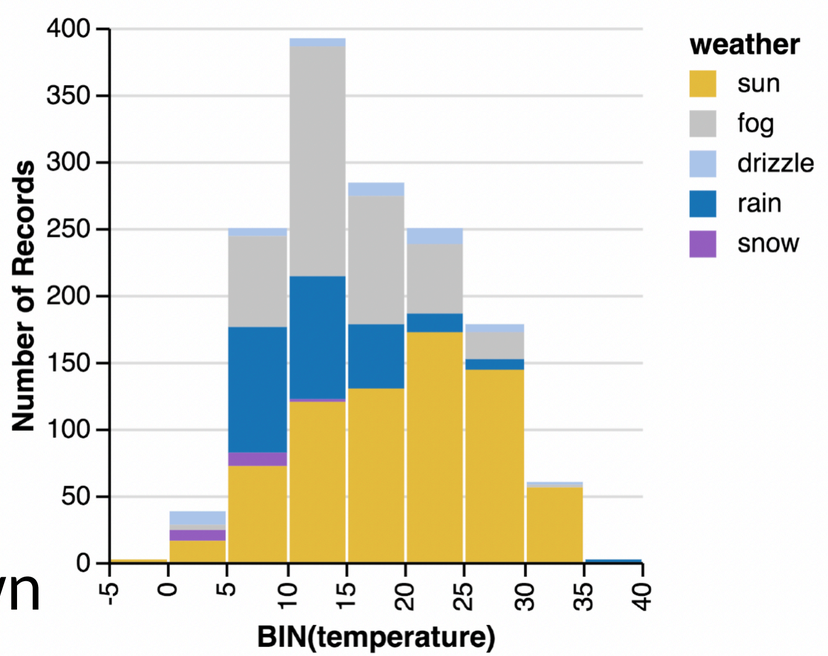
Arvind Satyanarayan, Dominik Moritz, Kanit Wongsuphasawat, Jeffrey Heer. IEEE Vis, 2017. Vega-Lite: A Grammar of Interactive Graphics
https://doi.org/10.1109/TVCG.2016.2599030

Vega-lite

Overriding the sensible defaults

```
{
  data: {url: "weather-seattle.json"},
  mark: "bar",
  encoding: {
    x: {
      bin: true,
      field: "temperature",
      type: "quantitative"
    },
    y: {
      aggregate: "count",
      type: "quantitative"
    },
    color: {
     field: "weather",
     type: "nominal"
    },
    scale: {
        domain: ["sun","fog","drizzle", "rain","snow"],
        range: ["#e7ba52","#c7c7c7","#aec7e8",
                "#1f77b4","#9467bd"]
    }
  }
}
```

Set our own color scale



Arvind Satyanarayan, Dominik Moritz, Kanit Wongsuphasawat, Jeffrey Heer. IEEE Vis, 2017. Vega-Lite: A Grammar of Interactive Graphics
https://doi.org/10.1109/TVCG.2016.2599030

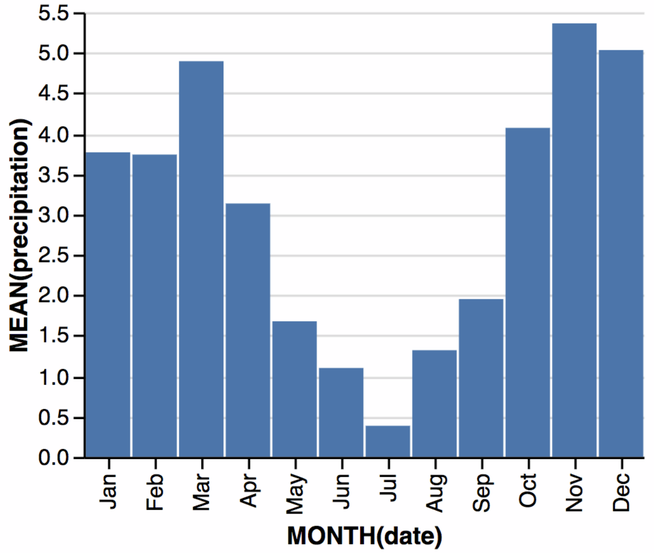
Vega-lite

Monthly precipitation

```
{
  data: {url: "weather-seattle.json"},
  mark: "bar",
  encoding: {
    x: {
      timeUnit: "month", field: "date",
      type: "quantitative"
    },
    y: {
      aggregate: "mean",
      field: "precipitation",
      type: "quantitative"
    }
  }
}
```

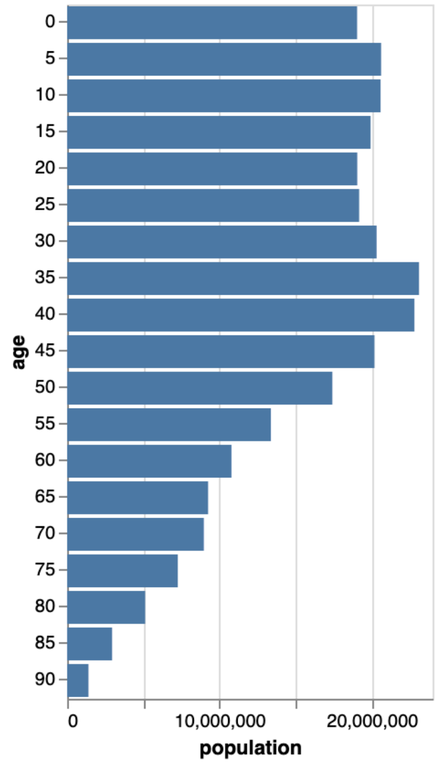
Field is a date string (“2018-10-17”), but display and bin it as a month

Aggregate by the mean



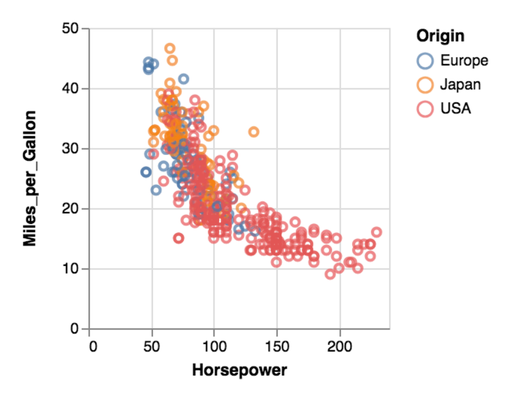
Arvind Satyanarayan, Dominik Moritz, Kanit Wongsuphasawat, Jeffrey Heer. IEEE Vis, 2017. Vega-Lite: A Grammar of Interactive Graphics
https://doi.org/10.1109/TVCG.2016.2599030

Vega-lite demo



Question

How would this visualization be specified in Vega-Lite?
(Assume field names are correct)



A

```
mark: "point",
  encoding: {
    x: {field: "MPG", type: "ordinal"},
    y: {field: “Horsepower", type: "ordinal"},
    color: {field: "Origin", type: "nominal"}
  }
```

B

```
mark: "point",
  encoding: {
    x: {field: "Horsepower", type: "quantitative"},
    y: {field: "MPG", type: "quantitative"},
    color: {field: "Origin", type: "nominal"}
  }
```

C

```
mark: "ticks",
  encoding: {
    x: {field: "Horsepower", type: "quantitative"},
    y: {field: "MPG", type: "quantitative"},
    color: {field: "Origin", type: "nominal"}
  }
```

D

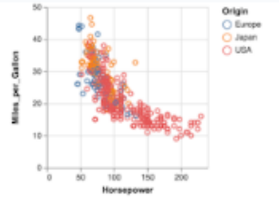
```
mark: "point",
  encoding: {
    x: {field: "Horsepower", type: "quantitative"},
    y: {field: "MPG", type: "quantitative"},
    color: {field: "Origin", type: "ordinal"}
  }
```

E

```
mark: "ticks",
  encoding: {
    x: {field: "MPT", type: "ordinal"},
    y: {field: “Horsepower", type: "ordinal"},
    color: {field: "Origin", type: "nominal"}
  }
```

How would this visualization be specified in Vega-Lite?

(Assume field names are correct)



A

```
mark: "point",
  encoding: {
    x: {field: "MPG", type: "ordinal"},
    y: {field: "Horsepower", type: "ordinal"},
    color: {field: "Origin", type: "nominal"}
  }
```

B

```
mark: "point",
  encoding: {
    x: {field: "Horsepower", type: "quantitative"},
    y: {field: "MPG", type: "quantitative"},
    color: {field: "Origin", type: "nominal"}
  }
```

C

```
mark: "ticks",
  encoding: {
    x: {field: "Horsepower", type: "quantitative"},
    y: {field: "MPG", type: "quantitative"},
    color: {field: "Origin", type: "nominal"}
  }
```

D

```
mark: "point",
  encoding: {
    x: {field: "Horsepower", type: "quantitative"},
    y: {field: "MPG", type: "quantitative"},
    color: {field: "Origin", type: "ordinal"}
  }
```

E

```
mark: "ticks",
  encoding: {
    x: {field: "MPT", type: "ordinal"},
    y: {field: "Horsepower", type: "ordinal"},
    color: {field: "Origin", type: "nominal"}
  }
```

A 0%

B 0%

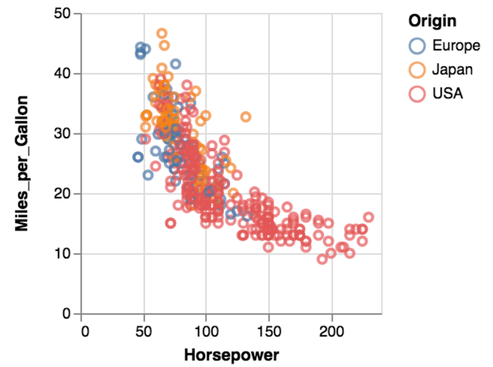
C 0%

D 0%

E 0%

Question

How would this visualization be specified in Vega-Lite?
(Assume field names are correct)



A

```
mark: "point",
  encoding: {
    x: {field: "MPG", type: "ordinal"},
    y: {field: “Horsepower", type: "ordinal"},
    color: {field: "Origin", type: "nominal"}
  }
```

B

```
mark: "point",
  encoding: {
    x: {field: "Horsepower", type: "quantitative"},
    y: {field: "MPG", type: "quantitative"},
    color: {field: "Origin", type: "nominal"}
  }
```

C

```
mark: "ticks",
  encoding: {
    x: {field: "Horsepower", type: "quantitative"},
    y: {field: "MPG", type: "quantitative"},
    color: {field: "Origin", type: "nominal"}
  }
```

D

```
mark: "point",
  encoding: {
    x: {field: "Horsepower", type: "quantitative"},
    y: {field: "MPG", type: "quantitative"},
    color: {field: "Origin", type: "ordinal"}
  }
```

E

```
mark: "ticks",
  encoding: {
    x: {field: "MPT", type: "ordinal"},
    y: {field: “Horsepower", type: "ordinal"},
    color: {field: "Origin", type: "nominal"}
  }
```

Sensible defaults: Vega-lite's secret

- Threshold is lower
  - More concise definitions, less to understand up front
- Ceiling remains the same
  - The sensible defaults can be overridden
- A downside: visualizations made with Vega-Lite look similar
  - The path of least resistance Vega-Lite provides influences what visualizations people make and what they look like

Downside: path of least resistance

- The path of least resistance: tools influence what is created
- Sensible defaults make Vega-Lite visualizations look similar to one another
  - These defaults *can* be overwritten, but are they in practice?
- Similar concern to the widespread adoption of grid frameworks

Today's goals

By the end of today, you should be able to…

- Write code which follows object-oriented principles in TypeScript
- Explain the advantages and disadvantages of using TypeScript
- Describe the concepts of threshold and ceiling in software tools and what tool designers should be striving to create
- Explain the relative threshold and ceilings of visualization tools like Protovis, D3, and Vega-Lite
- Describe common visualization primitives like marks, axes, and scales
- Implement simple visualizations with Vega-Lite

IN4MATX 133: User Interface Software

Lecture 7:
TypeScript &
Data Visualization Tools

A few more TypeScript details

Type declaration files

- Because types get stripped out when transpiling, a “declaration file” (`.d.ts`) can be created
  - Important when someone else will use your code as a library
  - Declaration file helps their code check types in your library
  - `tsc --declaration test.ts`
- You can install typings declarations for many libraries from npm
  - `npm install --save @types/your-library-here`

Type declaration files

```ts
//test.ts
function area(shape: string, width: number, height: number):string {
    var area:number = width * height;
    return "I'm a " + shape + " of area " + area + " cm^2.";
}

document.body.innerHTML = area('square', 15, 15);
```

```ts
// transpiled test.js
function area(shape, width, height) {
    var area = width * height;
    return "I'm a " + shape + " of area " + area + " cm^2.";
}
document.body.innerHTML = area('square', 15, 15);
```

```ts
// generated test.d.ts
declare function area(shape: string, width: number, height: number): string;
```

Interfaces

- Just like in Java, describes the “inputs” and “outputs” of an object

```
interface Shape {
    name: string;
    width: number;
    height: number;
    color?: string; // ? Specifies an "optional" value
}

function area(shape : Shape):string {
    var area = shape.width * shape.height;
    return "I'm " + shape.name + " with area " + area + " cm squared";
}

console.log(area({name: "rectangle", width: 30, height: 15}));
console.log(area({name: "square", width: 30, height: 30, color: “red"}));
```

Inheritance

- Like in Java, classes and interfaces can be extended

```
class Shape3D extends Shape {
    volume: number;

    constructor (name: string, width: number, height: number, length: number ) {
        super( name, width, height ); //calls base class constructor
        this.volume = length * this.area;
    };

    shoutout() { //overrides the base class
        return "I'm " + this.name +  " with a volume of " + this.volume + " cm cube.";
    }

    superShout() { //calls base class shoutout method
        return super.shoutout();
    }
}

var cube = new Shape3D("cube", 30, 30, 30);
console.log( cube.shoutout() );
console.log( cube.superShout() );
```

Generics

- Also work the same a Java

```
function identity<T>(arg: T): T {
    return arg;
}

let output = identity<string>("myString");  // type of
output will be 'string'
let output = identity("myString");  // type of output
will be 'string'
```

https://www.typescriptlang.org/docs/handbook/generics.html

Getter functions

- Also work the same a Java

```
const fullNameMaxLength = 10;

class Employee {
  private _fullName: string = "";

  get fullName(): string {
    return this._fullName;
  }

  set fullName(newName: string) {
    if (newName && newName.length > fullNameMaxLength) {
      throw new Error("fullName has a max length of " + fullNameMaxLength);
    }
    this._fullName = newName;
  }
}
```

https://www.typescriptlang.org/docs/handbook/generics.html