D3: The Crash Course

Chad Stolper

CSE 6242: Data and Visual Analytics

BUT FIRST….

Tufte's First Rule: DO NOT LIE!

Tufte's First Rule: DO NOT LIE!

Samantha

was ***not*** the genie on *I Dream of Genie.*

Tufte's First Rule: DO NOT LIE!

Samantha

was the witch on *Bewitched.*

D3: The Crash Course

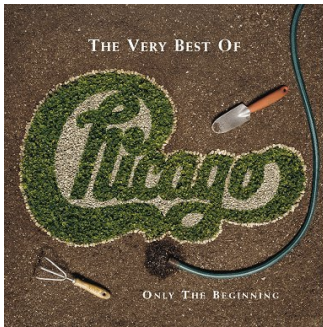
Chad Stolper

CSE 6242: Data and Visual Analytics

D3: The Early Sticking Points

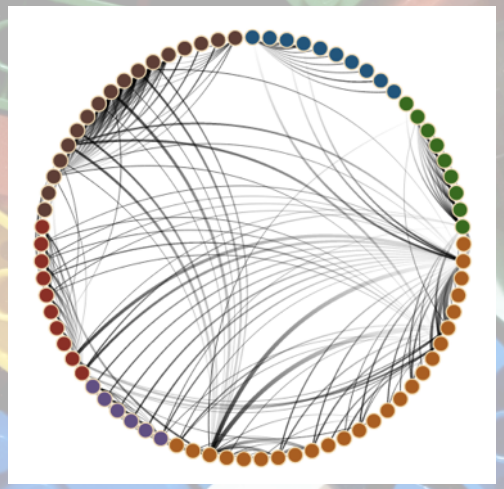
D3: Only the Beginning

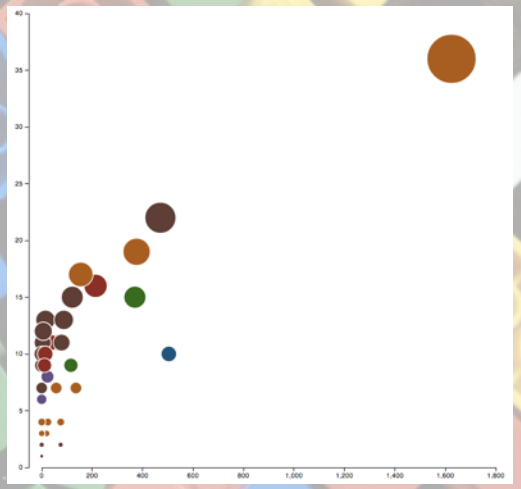
D3: Only the Beginning

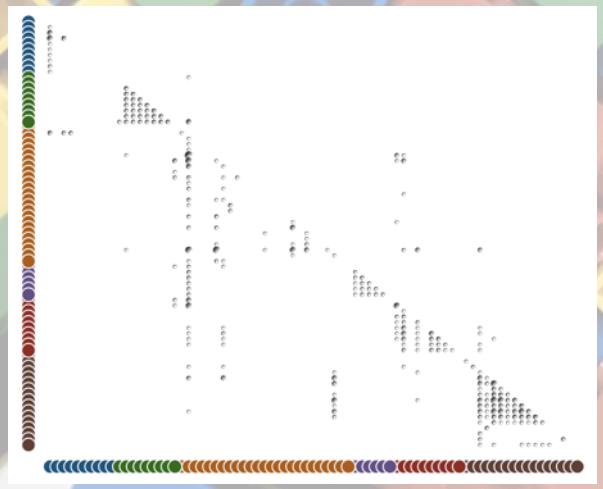


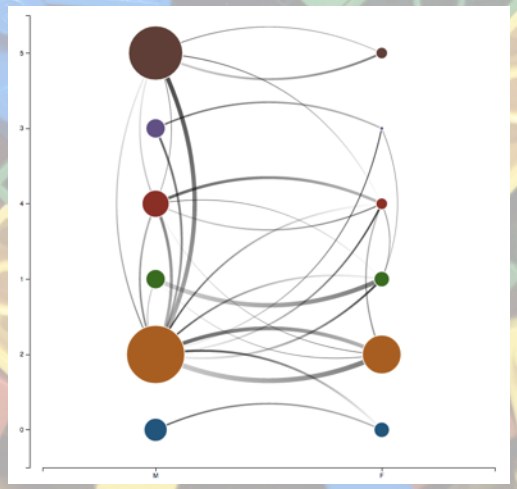
Please do not be afraid to ask questions!

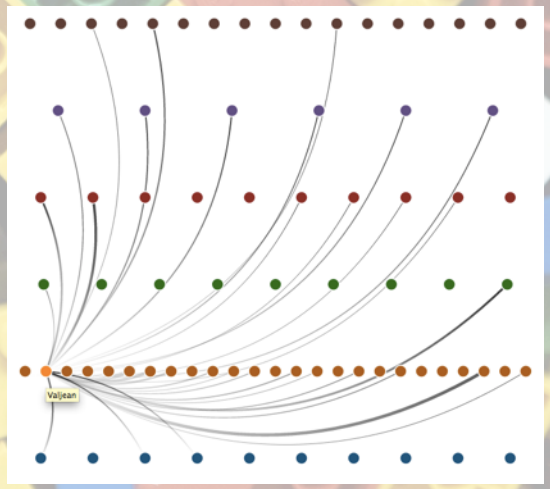
http://bl.ocks.org/mbostock/1256572










Valjean

http://www.bloomberg.com/graphics/2015-auto-sales/

- Website
  - Directory Structure
  - Development
- Javascript 101 and 102
- SVG Basics
- (Finally) D3.js Crash Course

Who has some programming experience?

Who has some web development experience?

Website Directory Structure

- (Replace “project” with a real name)

- project/
  - index.html
- project/lib/
  - d3.v3.js
- project/js/
  - project.js
- project/css/
- project/img/

Chrome Inspector and Console

- Open the webpage
- Right-click on anything
- Click inspect this element
- Click on the >= button at the top of the inspector to open the console as well
  - (2nd from the left)

Starting a Local Webserver

- `Python 2.x`
  - `python -m SimpleHTTPServer 8000`
- `Python 3.x`
  - `python -m http.server 8000`
- http://localhost:8000

How many of you have experience with Javascript?

Javascript 101

- All variables are global unless declared using var
  - x = 300 (global) vs. var x = 300 (local)
- Semicolons are optional
- “text” is the same as ‘text’
- JS arrays and objects are almost exactly the same syntax as python’s lists and dicts
- object.key is the same as object[‘key’]
- Print to the console using console.log( )

Javascript 102: Functional Programming

- Javascript is a *functional language*
  - Functions are themselves objects
  - Functions can be stored as variables
  - Functions can be passed as parameters
- D3 uses these abilities extensively!

Javascript 102: Functional Programming

- Javascript is a *functional language*
  - Functions are themselves objects
  - Functions can be stored as variables
  - Functions can be passed as parameters
- D3 uses these abilities extensively!

Array.map( )

- Used for applying a function to each element of an array

- The function provided as a parameter takes one parameter itself:
  - d: a/each data point

- https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Global_Objects/Array/map

Array.map( )

- var x = [{val:1},{val:2},{val:3},{val:4}]
- var a = x.map(function(d){
  return d.val;
  })
- a : [1,2,3,4]

MDN

- Mozilla Developer Network
- https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference
- (Easier: google “<command> mdn”)

Method Chaining

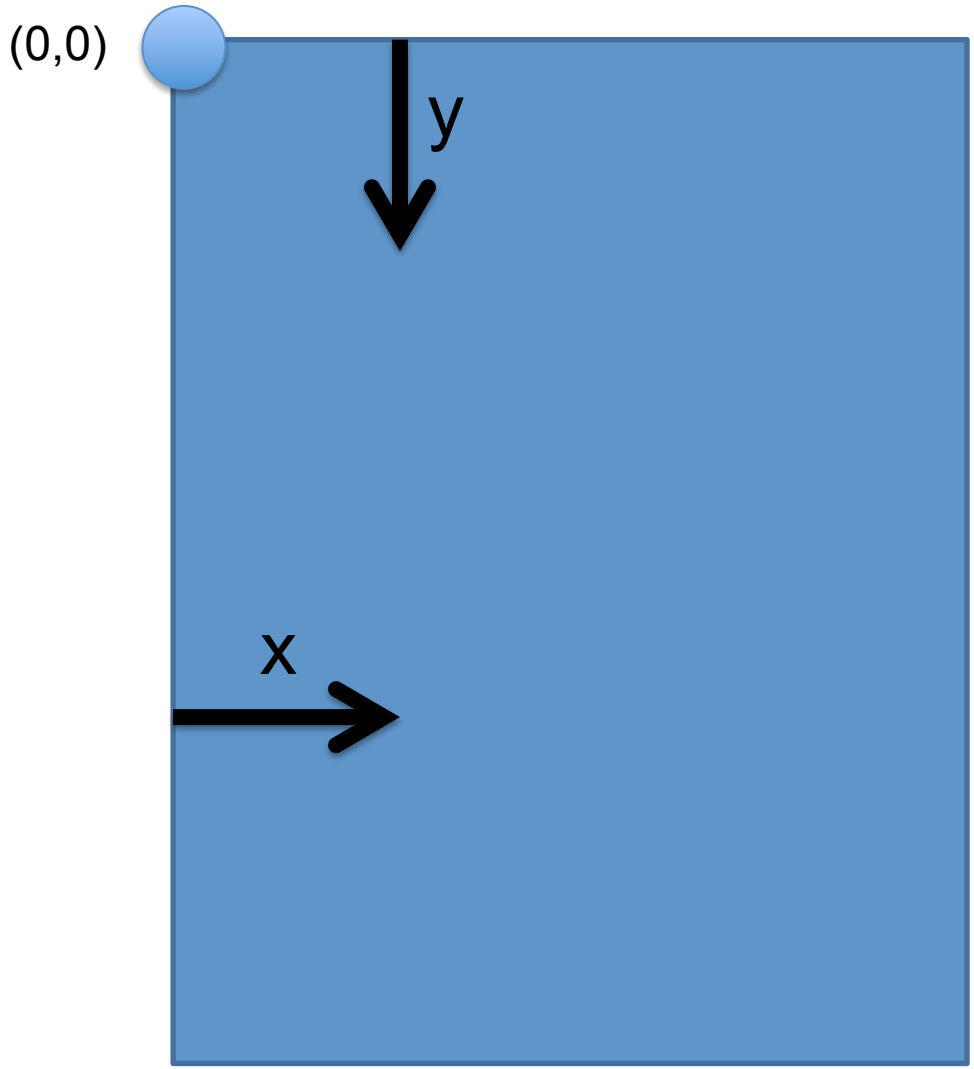
- "Syntactic Sugar" paradigm where each method returns the object that it was called on

```
group.attr("x",5).attr("y",5) //returns group
    is the same as
group.attr("x",5) //returns group
group.attr("y",5) //returns group
```

SVG BASICS

How many of you have experience with SVG?

How many have experience with 2D computer graphics (such as Java Swing)?


(0,0)
y
x

SVG Basics

SVG -> XML Vector Graphics

(Scalable Vector Graphics)

SVG Basics

- XML Vector Graphics
  - Tags with Attributes
  - <circle r=5 fill="green"></circle> 
- W3C Standard
  - http://www.w3.org/TR/SVG/
- Supported by all the major browsers

SVG Basics

- <svg>
- <circle>
- <rect>
- <path>
- <g>

SVG Basics

- <svg>
- <circle>
- <rect>
- <path>
- <g>
- <text> (after I've talked about D3)

<svg> element

- Overarching canvas

- (optional) Attributes:
  - width
  - height

```
<body>
  <div id="vis">
  </div>
</body>
```

- Create with
  - d3.select("#vis").append("svg:svg")

<svg> element

- Overarching canvas

- (optional) Attributes:
  - width
  - height

```
<body>
  <div id="vis">
      <svg></svg>
  </div>
</body>
```

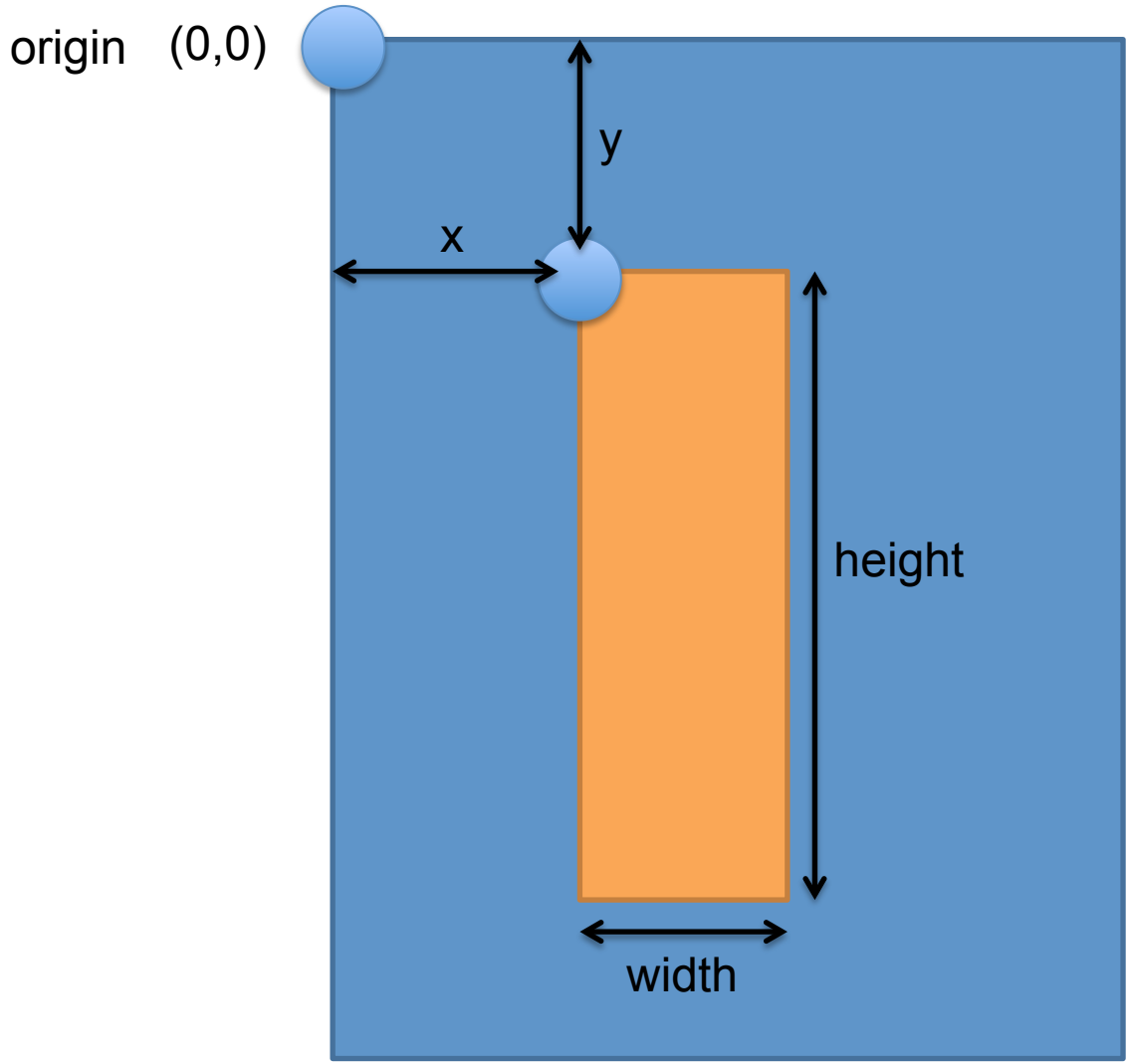
- Create with
  - d3.select("#vis").append("svg:svg")

<circle> element

- Attributes:
  - cx (relative to the LEFT of the container)
  - cy (relative to the TOP of the container)
  - r (radius)
- (optional) Attributes:
  - fill (color)
  - stroke (the width of the stroke)
  - stroke-fill (the color of the stroke)
- Create with
  - .append("svg:circle")

<rect> element

- Attributes:
  - x (relative to the LEFT of the container)
  - y (relative to the TOP of the container)
  - width (cannot be negative)
  - height (cannot be negative)
- (optional) Attributes:
  - fill (color)
  - stroke (the width of the stroke)
  - stroke-fill (the color of the stroke)
- Create with
  - .append("svg:rect")


origin (0,0)
y
x
height
width

Rather than positioning each element, what if we want to position (or style) a group of elements?

<g> element

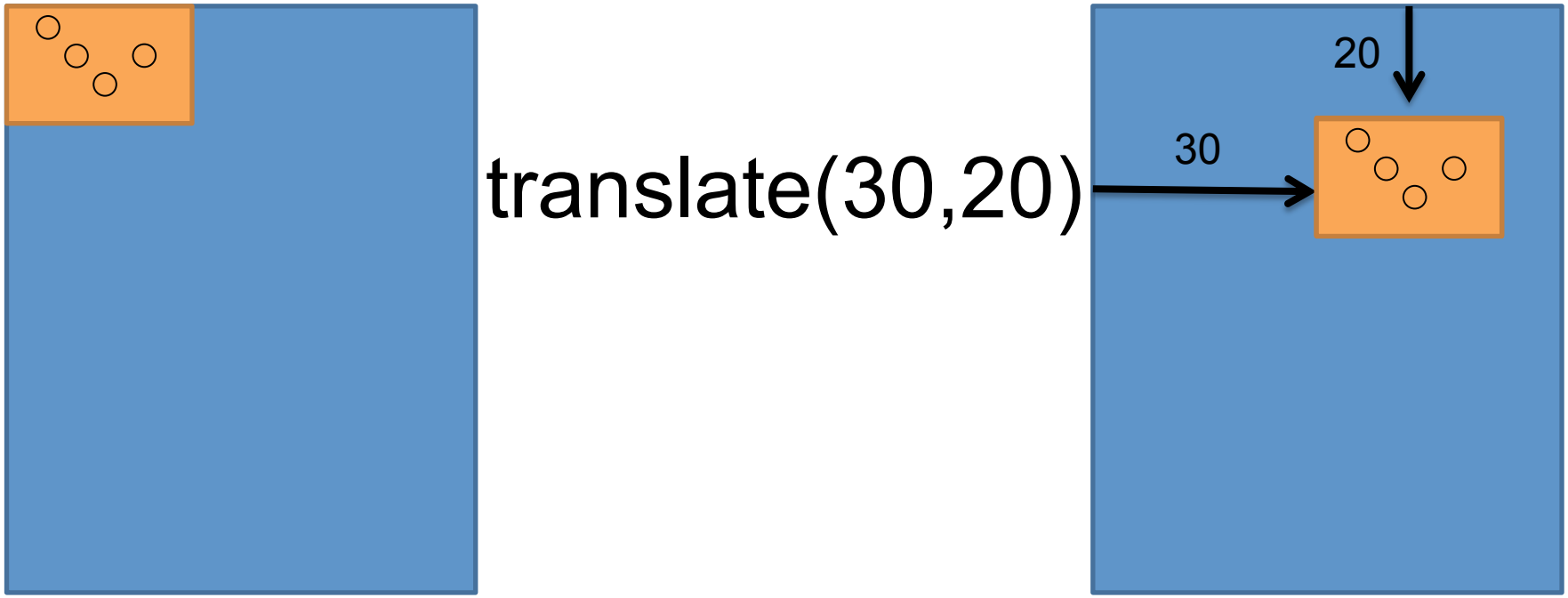
- Generic container (Group) element

- Attributes
  - transform
  - (fill,stroke,etc.)
- Create with:
  - var group = vis.append(“svg:g”)
- Add things to the group with:
  - group.append(“svg:circle”)
  - group.append(“svg:rect”)
  - group.append(“svg:text”)

Transform Property

“transform”, “translate(x,y)”

.attr("transform","translate(x,y)")



CSS Selectors Reference

- #vis → <tag id="vis">
- circle → <circle>
- .canary→ <tag class="canary">
- [color="blue"] → <tag color="blue">

- And any combinations…
  - AND
    - circle.canary → <circle class="canary">
  - OR
    - circle,.canary → <circle> <rect class="canary">

AND NOW D3…

Mike Bostock and Jeff Heer @ Stanford

2009- Protovis

Mike Bostock and Jeff Heer @ Stanford

2009- Protovis

Mike Bostock and Jeff Heer @ Stanford

2009- Protovis

2011- D3.js

New York Times

Univ. of Washington

Mike Bostock and Jeff Heer @ ~~Stanford~~

2009- Protovis

2011- D3.js

D3

- Grand Reductionist Statements

- Loading Data
- Enter-Update-Exit Paradigm
- Scales
- Axes
- Layouts
- Transitions and Interaction

- Where to go from here

D3.js in a Nutshell

D3 is a really powerful for-loop

with a ton of useful helper functions

D3

Declarative, domain-specific specification language for visualization

D3

Declarative, domain-specific specification language for visualization

Define a template for each type of element
D3 draws one element for each data point

Importing D3

```
<html >
    <head>
        <script src='lib/d3.v3.js' charset='utf-8'></script>
        <script src='js/project.js'></script>
    </head>
    <body>
        <div id="vis"></div>
    </body>

</html>
```

Importing D3

```
<html >
    <head>
        <script src='lib/d3.v3.js' charset='utf-8'></script>
        <script src='js/project.js'></script>
    </head>
    <body>
        <div id="vis"></div>
    </body>

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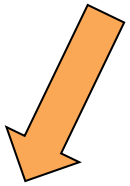
```

Importing D3



```
<html >
    <head>
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        <script src='js/project.js'></script>
    </head>
    <body>
        <div id="vis"></div>
    </body>

</html>
```

Importing D3

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<html >
    <head>
        <script src='lib/d3.v3.js' charset='utf-8'></script>
        <script src='js/project.js'></script>
    </head>
    <body>
        <div id="vis"></div>
    </body>

</html>
```

Assigning the Canvas to a Variable

```
var vis = d3.select("#vis")
    .append("svg:svg")
```

```
<body>
        <div id="vis"><svg></svg></div>
</body>
```

Loading Data

- d3.csv(fileloc,callback)
- d3.json(fileloc,callback)

- fileloc: string file location
  - “data/datafile.csv”
- callback: function(rawdata){ }

rawdata from a CSV file

```
[
  {
    'name': 'Adam',
    'school': 'GT',
    'age': '18'
  },
  {
    'name': 'Barbara',
    'school': 'Emory',
    'age': '22'
  },
  {
    'name': 'Calvin',
    'school': 'GSU',
    'age': '30'
  }
]
```

name	school	age
Adam	GT	18
Barbara	Emory	22
Calvin	GSU	30

Problem

```
[
  {
    'name': 'Adam',
    'school': 'GT',
    'age': '18'
  },
  {
    'name': 'Barbara',
    'school': 'Emory',
    'age': '22'
  },
  {
    'name': 'Calvin',
    'school': 'GSU',
    'age': '30'
  }
]
```

- Ages are Strings!
- They should be ints!
- We can fix that:

```
for(var d: data){
    d = data[d]
    d.age = +d.age
}
```

rawdata from a CSV file

```
[
  {
    'name': 'Adam',
    'school': 'GT',
    'age': 18
  },
  {
    'name': 'Barbara',
    'school': 'Emory',
    'age': 22
  },
  {
    'name': 'Calvin',
    'school': 'GSU',
    'age': 30
  }
]
```

name	school	age
Adam	GT	18
Barbara	Emory	22
Calvin	GSU	30

Enter-Update-Exit

- The *most* critical facet of how D3 works

- If you remember nothing else from today, remember this...
- “Enter-Update-Exit”
- “Enter-Update-Exit”
- “Enter-Update-Exit”

Enter-Update-Exit

- The *most* critical facet of how D3 works

- If you remember nothing else from today, remember this...
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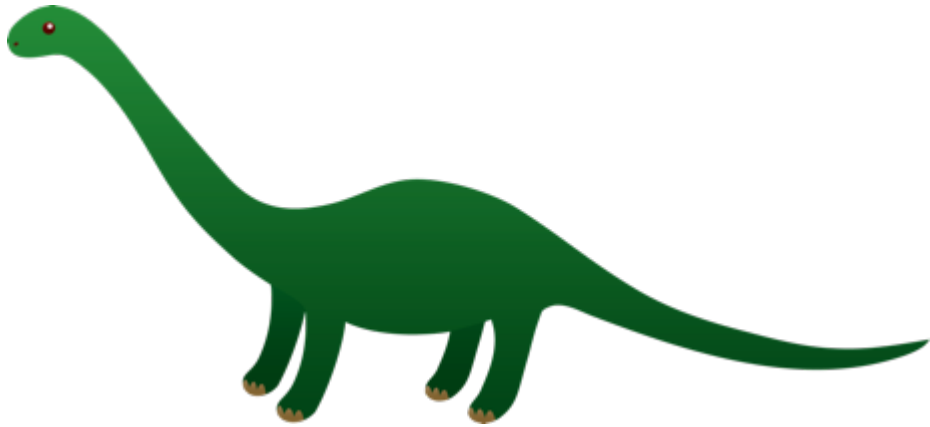

Enter-Update-Exit

- Pattern:
  - Select a “group” of “elements”
  - Assign data to the group
  - **Enter**: Create new elements for data points that don’t have them yet
  - **Update**: Set the attributes of all the elements based on the data
  - **Exit**: Remove elements that don’t have data anymore

Can be hard to grok:

You can select groups of elements that DON'T EXIST YET

.enter( ) and .exit( )

- .enter( )
  - New data points

- .exit( )
  - Old data points

- .enter() and .exit() only exist when .data() has been called

.enter( ) and .exit( )

- .enter( )
  - New data points

- .exit( )
  - Old data points

- .enter() and .exit() only exist when .data() has been called

.enter( ) and .exit( )

- .data([1,2,3,4])
- .data ([1,2,3,4,5,6])
- .data ([1,2,3]) //4,5,6

Data Key Functions

- .data(rawdata) defaults to assuming that the index of the point is the key
- .data(rawdata, function(d,i){ }) allows you to set a key functions
- e.g.
  - .data(rawdata, function(d,i){ return d.id; })
  - .data(rawdata, function(d,i){ return d.name; })

E-U-E Pattern Template

```
var group = vis.selectAll(“rect”)
        .data(rawdata) //rawdata must be an array!
group.enter( ).append(“svg:rect”) //ENTER!
        .attr( )
        .attr( )
group //UPDATE!
        .attr( )
        .attr( )
group.exit( ).remove( ) //EXIT!
```

WARNING!!!!

E-U-E Pattern Template

```
var group = vis.selectAll("rect")
        .data(rawdata) //rawdata must be an array!
group.enter( ).append("svg:rect") //ENTER!
        .attr( )
        .attr( )
group //UPDATE!
        .attr( )
        .attr( )
group.exit( ).remove( ) //EXIT!
```

Many online examples

E-U-E Pattern Template

```
var group = vis.selectAll("rect")
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group.enter( ).append("svg:rect") //ENTER!
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```

Many online examples drop the variable name before .enter()

E-U-E Pattern Template

```
var group = vis.selectAll("rect")
        .data(rawdata) //rawdata must be an array!

group.enter( ).append("svg:rect") //ENTER!
        .attr( )
        .attr( )
group //UPDATE!
        .attr( )
        .attr( )

group.exit( ).remove( ) //EXIT!
```

Many online examples drop the variable name before .enter()

I *highly* recommend you don't!

.attr( )

- The Attribute Method
- Sets attributes such as x, y, width, height, and fill

- Technical details:
  - group.attr(“x”, 5)
  - <rect x=“5”></rect>

.attr( ) and Functional Programming

- [{size: 10}, {size: 8}, {size: 12.2}]

- .attr("height", function(d,i){ return d.size })
  - d: the data point
- .attr("x", function(d,i){ return (i+1)*5; })
  - i: the index of the data point

<rect height="10" x="5"></rect>
<rect height="8" x="10"></rect>
<rect height="12.2" x="15"></rect>

<text> elements

<text> elements

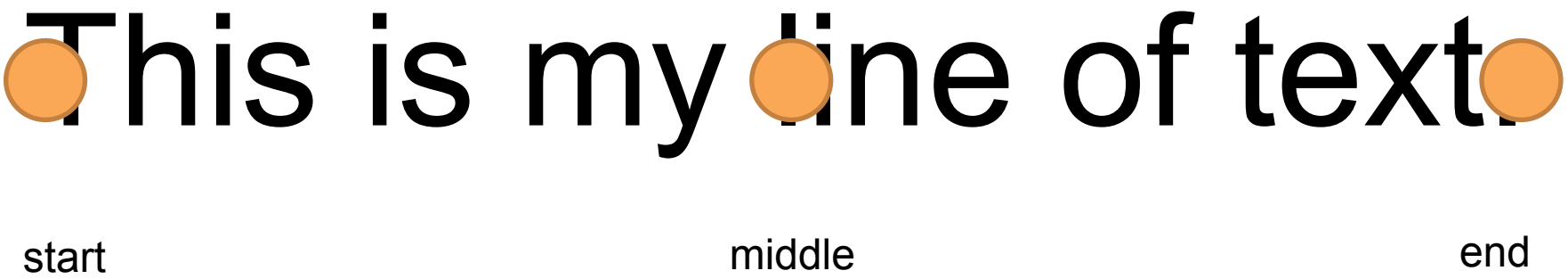
- I'm going to apologize in advance here for the lousy job the W3C did with the <text> definition.
- You're going to have to just either memorize these things or keep referring back to http://www.w3c.org/TR/SVG/text.html (first Google hit for "svg text") like I do.

<text> elements

- Extra Method in D3
  - .text("Your Text Goes Here")
  - <tag>Your Text Goes Here</tag>
- Attributes
  - x
  - y
- Styles
  - text-anchor: start, middle, end
  - dominant-baseline: [nothing], hanging, middle

text-anchor style

Where is (0,0)?



dominant-baseline style

Where is (0,0)?

<text> example

```
group.append("svg:text")
        .text(function(d){return d.name})
        .attr("x", function(d,i){return i*5})
        .attr("y", function(d,i){return height;})
        .style("dominant-baseline","hanging")
        .style("text-anchor", "middle")
```

The .style() Function

Like attr, but for the style attribute

- Inline css styling

.style(“prop1”,“val1”)

.style(“prop2”,“val2”)

.style(“prop3”, function(d,i){ })

<ele style=“prop1: val1; prop2: val2;”>

<text> example

```
group.append("svg:text")
        .text(function(d){return d.name})
        .attr("x", function(d,i){return i*5})
        .attr("y", function(d,i){return height;})
        .style("dominant-baseline","hanging")
        .style("text-anchor", "middle")
```

What if you have

two different types of circles?

Classing

- CSS Classes
  - Any number of classes per element
  - Select using ".classname"

```
red = vis.selectAll("circle.redcircle")
      .data(reddata, function(d){return d.id;})

red.enter( ).append("svg:circle")
      .classed("redcircle","true")

blue = vis.selectAll("circle.bluecircle")
      .data(bluedata, function(d){return d.id;})

blue.enter( ).append("svg:circle")
      .classed("bluecircle", "true")

vis.selectAll(".bluecircle").attr("fill","blue")

red.attr("fill","red")
```

- .attr(“height”, 5) is boring
- .attr(“height”, function(d,i){ return i*5; }) only works for fixed values
- .attr(“height”, function(d){ return d; }) can blow up really quickly…

Scales

Scales

- D3 has many types of scales
- I am only going to cover two:
  - Linear Scales
  - Ordinal Scales

Linear Scales

- var xscale = d3.scale.linear( )
  .domain([min, max])
  .range([minOut, maxOut])

- group.attr("x", function(d,i){
  return xscale(d.size);
  })

- y = mx+b

Min and Max

But how do you figure out the min and max for the domain?

D3

A really powerful for-loop with a ton of useful helper functions

D3

A really powerful for-loop with a ton of useful helper functions

Min and Max

- d3.min([ ]) → number
- d3.max([ ]) → number
- d3.extent([ ]) → [number,number]

Min and Max

- d3.min([ ]) → number
- d3.max([ ]) → number
- d3.extent([ ]) → [number,number]

- All can be combined with
  - .map(function(d){ }), which returns an [ ]

```
d3.min(
    data.map( function(d){ return d.age; })
) // returns the minimum age
```

Linear Scales

- You can even keep the same scale, and just update the domain and/or range as necessary
- Note: This will not ***update*** the graphics all on its own

Ordinal Scales

- D3 has built-in color scales!
  - (And they're easy!)

- var colorscale = d3.scale.category10( )

- Also available are:
  - category20( )
  - category20b( )
  - category20c( )
  - (and even a few more)

~~Ordinal~~ Categorical Scales

- D3 has built-in color scales!
  - (And they're easy!)

- var colorscale = d3.scale.category10( )

- Also available are:
  - category20( )
  - category20b( )
  - category20c( )
  - (and even a few more)

~~Ordinal~~ Categorical Scales

- [{type:‘Bird’},{type:‘Rodent’},{type:‘Bird’}]
- var colorscale = d3.scale.category10( )
- .attr(“fill”,function(d,i){
  return colorscale(d.type)
  }
  - <rect fill=“blue”></rect>
  - <rect fill=“orange”></rect>
  - <rect fill=“blue”></rect>

Axes

D3 also has *visual* helper-functions

Axes

- yaxisglyph = vis.append(“g”)

```
yaxis = d3.svg.axis( )
    .scale( yscale ) //must be a numerical scale
    .orient( ‘left’ ) //or ‘right’ or ‘top’ or ‘bottom’
    .ticks( 6 ) //number of ticks, default is 10

yaxisglyph.call(yaxis)
```

D3 even has some

entire techniques built in…

http://bl.ocks.org/mbostock/4063582

What if the data is changing?

E-U-E Pattern Template

```
var group = vis.selectAll(“rect”)
        .data(rawdata) //rawdata must be an array!
group.enter( ).append(“svg:rect”) //ENTER!
        .attr( )
        .attr( )
group //UPDATE!
        .attr( )
        .attr( )
group.exit( ).remove( ) //EXIT!
```

E-U-E Pattern Template

```
function redraw(rawdata){
    var group = vis.selectAll("rect")
        .data(rawdata) //rawdata must be an array!
    group.enter( ).append("svg:rect") //ENTER!
        .attr( )
        .attr( )
    group //UPDATE!
        .attr( )
        .attr( )
    group.exit( ).remove( ) //EXIT!

}
```

E-U-E Pattern Template

```
function redraw(rawdata){
    var group = vis.selectAll("rect")
        .data(rawdata) //rawdata must be an array!
    group.enter( ).append("svg:rect") //ENTER!
        .attr( )
        .attr( )
    group.transition() //UPDATE!
        .attr( )
        .attr( )
    group.exit( ).remove( ) //EXIT!

}
```

Transitions

- CSS3 transitions with D3 are ***magical!***
- D3 interpolates values for you…

Transitions

```
rect.attr("height", 0)
rect.transition( )
    .delay( 500 ) //can be a function of data
    .duration(200) //can be a function of data
    .attr("height", 5)
```

So transitions allow a vis to be dynamic…

But they're not really interactive…

Interaction

The on( ) Method

.on( )

```
rect.on (“click”, function(d){
    d.color = “blue”;
    redraw( )

})
```

HTML Events

- click
- mouseover
- mouseenter
- mouseout
- etc.

Where to get learn more…

- http://d3js.org/
  - Tons of examples and basics.
- https://github.com/mbostock/d3/wiki/API-Reference
  - Official D3 documentation. Extremely well done.
- https://github.com/mbostock/d3/wiki/Tutorials
  - List of seemingly ALL the tutorials online
- The Google/StackOverflow combination
  - (my personal favorite)

Live Coding

http://phrogz.net/js/d3-playground/

Once You're Comfortable…

d3.Chart

http://misoproject.com/d3-chart/

When You're Bored…

http://www.koalastothemax.com/

Thanks!

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Good Luck!

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Questions?

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