D3: The Crash Course
aka: D3: The Early Sticking Points
aka: D3: Only the Beginning

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D3 Show Reel

[Graph showing stock price movements for multiple companies]

Chad Stolper

CSE 6242 Guest Lecture
**Pickups are king of the road.**

Automakers sold more than 16.5 million new vehicles in the U.S. last year, up 5.9 percent from 2013. The most popular model, by a huge stretch, was the Ford F-Series pickup. In 2014, Americans bought 754,000 of them, making it the top-selling vehicle for the 33rd year in a row.

The F-Series trucks alone beat Volkswagen’s total U.S. sales. And Lincoln’s. And Cadillac’s. And Mitsubishi’s. Combined.

Ford’s F-Series: America’s best-selling vehicle
BUT FIRST....
Why should you learn D3???
If you visualization/system/tool will benefit from interactivity.

Otherwise, use anything you want
(e.g., tableau, excel, python:seaborn, R:ggplot2, etc.)

More online discussion: https://news.ycombinator.com/item?id=11995332
D3 v4.0.0 released (github.com)

438 points by aw3c2 224 days ago | hide | past | web | 94 comments | favorite

yoavm 224 days ago [-]

D3 has the reputation of being super-complicated because of all the libraries that are based on it, "simplifying" it so that everyone can use it. In the past year I wanted to create pretty unique type of data visualisation, so I dived into D3 and discovered it makes a lot more sense than I thought. Of course, if you only want a regular bar chart, you'll do better with things like C3, nvd3 etc'. But if you want anything a bit special, D3 itself is very powerful and the documentation in pretty good - there's no reason to avoid using it directly.

Definitely looking forward to try the new release.

minimaxir 224 days ago [-]

To add to that, if you are a complete newbie to any data visualization, do not start with d3. If you want to make pretty charts programatically, using R/ggplot2 or Python/Seaborn is good enough. Even Excel is fine if you tweak the defaults.

D3 is good if your visualization benefits from interactivity, either with dynamic data adjustment or rich tooltips. But static visualizations are important too. (I recently restructured my workflow so I can output static images and interactive charts with the same code, which makes it the best of both worlds.)

danso 224 days ago [-]

What is your static+interactive workflow now, if I can ask? Also, is it fairly easy to build a workflow that generates static visualizations via D3 (i.e. making savable SVGs)?

minimaxir 224 days ago [-]

I make charts with R/ggplot2. Standard workflow is to construct chart and save as static file. (PNG/SVG etc.) But with the plot.ly bridge, I can convert to an interactive chart w/ rich
This lectures and HW2 is about D3 ver.3

- Ver4 is the latest, but has “breaking” changes.
- Most D3 examples/tutorials are still using v3
- Ver4 vs ver3: [https://iros.github.io/d3-v4-whats-new/#1](https://iros.github.io/d3-v4-whats-new/#1)
- Upgrading Ver3 code to ver4 code: [https://keithpblog.wordpress.com/2016/07/31/upgrading-d3-from-v3-to-v4/](https://keithpblog.wordpress.com/2016/07/31/upgrading-d3-from-v3-to-v4/)
Chrome Inspector and Console

- Open the webpage
- Right-click on anything
- Click “inspect”
- Open the console too, so you can see the error messages
Starting a Local Web Server


Necessary for Chrome, not for Safari or Firefox
(This is a security measure: to prevent reading from your file systems)

- **Python 2.x**
  - python -m SimpleHTTPServer 8000
- **Python 3.x**
  - python -m http.server 8000
- **http://localhost:8000**
If you’re new to JavaScript...

prepare for a lot of...

confusion (wat??)

and hair pulling

I’m serious.

If you’re new to Javascript…

https://www.destroyallsoftware.com/talks/wat

(starting 1:20)
Javascript 101

- All variables are global, unless declared using `var`
  - `x = 300` (global)
  - `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 supports **functional programming**
- Functions are themselves objects
- Functions can be stored as variables
- Functions can be **passed as parameters**

**D3 uses these abilities extensively!**

Some people say javascript is a “multi-paradigm” programming language. http://stackoverflow.com/questions/3962604/is-javascript-a-functional-programming-language
What does that mean?


Examples

Mapping an array of numbers to an array of square roots

The following code takes an array of numbers and creates a new array containing the square roots of the numbers in the first array.

```
1 var numbers = [1, 4, 9];
2 var roots = numbers.map(Math.sqrt);
3 // roots is now [1, 2, 3], numbers is still [1, 4, 9]
```

Passing Math.sqrt (a function) as a parameter
Array.map( )

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

- The function provided (Math.sqrt) takes one value as input (e.g., 9) and output another value (e.g., 3).

```javascript
1 var numbers = [1, 4, 9];
2 var roots = numbers.map(Math.sqrt);
3 // roots is now [1, 2, 3], numbers is still [1, 4, 9]
```
MDN – the BEST Javascript reference

• Mozilla Developer Network


• (Easier: google “<command> mdn”)
Method Chaining

• “Syntactic Sugar” paradigm where each method returns the object that it was called on

```javascript
group
  .attr("x",5)
  .attr("y",5); //returns group
```

is the same as

```javascript
group.attr("x",5) //returns group
group.attr("y",5) //returns group
```
SVG BASICS

SVG = Scalable Vector Graphics

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/](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 drawing board

- (optional) Attributes:
  - width
  - height

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

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

- Overarching canvas

- (optional) Attributes:
  - width
  - height

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

<body>
  <div id="vis">
    <svg></svg>
  </div>
</body>
<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 color of the stroke)
  - stroke-width (the width of the stroke)
- Create with
  - `.append("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 color of the stroke)
  – stroke-width (the width of the stroke)

• Create with
  – .append("rect")
origin(0,0)

width

height

x

y
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("g")`

- Add things to the group with:
  - `group.append("circle")`
  - `group.append("rect")`
  - `group.append("text")`
CSS Selectors Reference

- `#vis` ➔ `<tag id="vis">`
- `circle` ➔ `<circle>`
- `.canary` ➔ `<tag class="canary">`
- `[color="blue"]` ➔ `<tag color="blue">`
- And many more ways
  - [http://www.w3schools.com/cssref/css_selectors.asp](http://www.w3schools.com/cssref/css_selectors.asp)

- And any combinations...
  - **AND**
    - `circle.canary` ➔ `<circle class="canary">`
  - **OR**
    - `circle, .canary` ➔ `<circle>  <circle class="canary">  <tag 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
Mike Bostock and Jeff Heer @ Stanford
2009- Protovis
2011- D3.js
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 manipulating the DOM
Importing D3

<html>
  <head>
    <script src='lib/d3.js' charset='utf-8'></script>
    <script src='js/project.js'></script>
  </head>
  <body>
    <div id="vis"></div>
  </body>
</html>
<html>
<head>
  <script src='lib/d3.js' charset='utf-8'></script>
  <script src='js/project.js'></script>
</head>
<body>
  <div id="vis"></div>
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Importing D3

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Importing D3

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Importing D3

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<html>
  <head>
    <script src='lib/d3.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

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

```html
<body>
    <div id="vis"><svg></svg></div>
</body>
```
Loading Data

• `d3.csv(fileloc, callback)`
• `d3.tsv(fileloc, callback)`
• `d3.json(fileloc, callback)`

• `fileloc`: string file location
  – “data/datafile.csv”
• `callback`: `function(rawdata){ }`
rawdata from a CSV file

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

<table>
<thead>
<tr>
<th>name</th>
<th>school</th>
<th>age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adam</td>
<td>GT</td>
<td>18</td>
</tr>
<tr>
<td>Barbara</td>
<td>Emory</td>
<td>22</td>
</tr>
<tr>
<td>Calvin</td>
<td>GSU</td>
<td>30</td>
</tr>
</tbody>
</table>
Problem

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

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

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

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

rawdata from a CSV file

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

<table>
<thead>
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<th>name</th>
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</tr>
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</tr>
<tr>
<td>Calvin</td>
<td>GSU</td>
<td>30</td>
</tr>
</tbody>
</table>
rawdata from a CSV file

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

<table>
<thead>
<tr>
<th>name</th>
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<td>22</td>
</tr>
<tr>
<td>Calvin</td>
<td>GSU</td>
<td>30</td>
</tr>
</tbody>
</table>

Ok, so let’s map this data to visual elements!
D3

Declarative, domain-specific specification language for manipulating the DOM

Define a **template** for each element
D3 draws one element for each data point
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

Pattern:

- Select a “group” of “elements” (e.g., circles)
- Assign data to the group
- **Enter**: Create new elements for data points not associated with any elements yet (and set constant or initial attribute values)
- **Update**: Set the attributes of all the elements based on the data
- **Exit**: Remove elements that don’t have data anymore
.enter( ) and .exit( )

- .data( [1,2,3,4] )
  - Enter: [1,2,3,4]
  - Update: [1,2,3,4]
  - Exit: [ ]

- .data( [1,2,3,4,5,6] )
  - Enter: [5,6]
  - Update: [1,2,3,4,5,6]
  - Exit: [ ]

- .data( [1,2,3] )
  - Enter: [ ]
  - Update: ???
  - Exit: [4,5,6]
.enter( ) and .exit( )

- .data([1,2,3,4])
  - Enter: [1,2,3,4]
  - Update: [1,2,3,4]
  - Exit: []

- .data([1,2,3,4,5,6])
  - Enter: [5,6]
  - Update: [1,2,3,4,5,6]
  - Exit: []

- .data([1,2,3])
  - Enter: []
  - Update: [1,2,3,4,5,6]
  - Exit: [4,5,6]
.enter( ) and .exit( )

- .enter( )
  - New data points

- .exit( )
  - Elements to be removed

- .enter() and .exit() only exist when .data() has been called
Can be hard to grok:
You can select groups of elements that DON’T EXIST YET

http://bost.ocks.org/mike/join/
Still confused?

Excellent interactive demo to explain enter-update-exit:
http://niceone.org/examples/d3-selections/

Full tutorial:
https://medium.com/@c_behrens/enter-update-exit-6cafc6014c36#.dqwkermdb
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 function
- e.g.
  - `.data(rawdata, function(d,i){ return d.id; })`
  - `.data(rawdata, function(d,i){ return d.name; })`
E-U-E Pattern Template

```javascript
var group = vis.selectAll("rect")
  .data(rawdata) // rawdata must be an array!
group.enter().append("rect")  // ENTER!
  .attr()
  .style()
group  // UPDATE!
  .attr()
  .style()
group.exit().remove()  // EXIT!
```
WARNING!!!!
E-U-E Pattern Template

```javascript
var group = vis.selectAll("rect")
  .data(rawdata) // rawdata must be an array!
group.enter().append("rect") // ENTER!
  .attr()
  .style()

// UPDATE!

// UPDATE!

// EXIT!

// EXIT!
```

Many online examples
E-U-E Pattern Template

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

group.enter().append("rect") //ENTER!
    .attr()
    .style(); //UPDATE!

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

Many online examples drop the variable name before `enter()`.
E-U-E Pattern Template

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

Many online examples drop the variable name before .enter()
I highly recommend you don’t!

group.enter().append("rect") // ENTER!
  .attr()
  .style()

group // UPDATE!
  .attr()
  .style()

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

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

We want 3 rectangles:
<rect height="10" x="5"></rect>
<rect height="8" x="10"></rect>
<rect height="12.2" x="15"></rect>

.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
<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
Where is (0,0)?

This is my line of text.

start  middle  end
dominant-baseline style

Where is (0,0)?

This is my line of text.
<text> example

Start
Middle
End

<text x="50" y="20"
    style="text-anchor: start">
  Start
</text>
<text x="50" y="40"
    style="text-anchor: middle">
  Middle
</text>
<text x="50" y="60"
    style="text-anchor: end">
  End
</text>

http://tutorials.jenkov.com/svg/text-element.html
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;">
Example

```javascript
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")
```

Need to remember what to use `.style` and when to use `.attr`
What if you have two different types of circles?
Classing

- **CSS Classes**
  - Any number of classes per element
  - Select using “.classname”

```javascript
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")
```
Scales
(e.g., sizing a circle based on data value)
.attr("height", function(d){ return d; })

can blow up really quickly...
Scales

- D3 has many types of scales
- I am only going to cover two:
  - Linear Scales
  - Ordinal Scales
var xscale = d3.scale.linear()
  .domain([min, max])
  .range([minOut, maxOut])

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

D3.js – scale (Domain and Range)

```javascript
var data = [4, 8, 15, 16, 23, 42];

var x = d3.scale.linear()
    .domain([0,d3.max(data)])
    .range([0, 420]);

Value range of the dataset
Value range for the visualized graph
```

http://image.slidesharecdn.com/d3-140708145630-phpapp02/95/d3-17-638.jpg?cb=1404831405
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]
An optional *accessor* function may be specified, which is equivalent to calling *array.map(accessor)* before computing the maximum value.

```javascript
d3.max(
    data.map( function(d){ return d.age; } )
) // returns the maximum age
```

var `maxAge` = d3.max(
    data.map( function(d){ return d.age; } )
) // returns the maximum age

var `yscale` = d3.scale.linear( ).domain([0, `maxAge`]).range([0, 100]);
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)

Think carefully before using a rainbow palette for ordinal data!
http://www.mathworks.com/tagteam/81137_92238v00_RainbowColorMap_57312.pdf
Ordinal Categorical Scales

- [ {type: 'Bird'}, {type: 'Rodent'}, {type: 'Bird'} ]
- var colorscale = d3.scale.category10()
- .attr("fill", function(d, i){
  return colorscale(d.type)
})
Ordinal Categorical Scales

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

Bird  Blue
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>
  -
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>

Bird  Blue
Rodent  Orange
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>
  -
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 fill="orange"/>
  - <rect fill="blue"/>
D3 also has *visual* helper-functions
Axes

```javascript
yaxisglyph = vis.append("g")

yaxis = d3.svg.axis()
    .scale(yscale) // must be a numerical scale
    .orient('left') // or 'right', 'top', or 'bottom'
    .ticks(6) // number of ticks, default is 10
yaxisglyph.call(yaxis)
```
D3 even has some entire techniques built in (e.g., treemap)...

http://bl.ocks.org/mbostock/4063582
What if the data is changing?
E-U-E Pattern Template

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

```javascript
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()
        .attr()
    group.exit().remove() // EXIT!
}
```
E-U-E Pattern Template

```javascript
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

```javascript
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) //can be a function of data
  .style("fill","green") //can be a function of data
```
So transitions allow a vis to be dynamic...
But they’re not really interactive...
Interaction

The on( ) Method
rect.on ("click", function(d) {
    d.color = "blue";
    redraw( rawdata )
})

**HTML Events**
- click
- mouseover
- mouseenter
- mouseout
- etc.
`.on()`

```javascript
rect.on ("click", function(d)
    d.color = "blue";
    redraw( rawdata )
})
```

**HTML Events**
- click
- mouseover
- mouseenter
- mouseout
- etc.

*d is the data point backing the element clicked on*
Where to get learn more...

- The Google/StackOverflow combination - (my personal favorite)
When You’re Bored...

http://www.koalastothemax.com/
Thanks!

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Good Luck!

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Questions?

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